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Assessment of Dental Implant Stability and Its Influence on Osseointegration

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ABSTRACT

Objective: *The aim of this study was to analyze the clinical outcomes of dental implant treatment in patients.* ***Method:*** *A total of 149 implants in 41 patients were observed over five years using a standard two-stage protocol. The study included clinical examination methods, palpation, percussion, dynamometry, and resonance frequency analysis (RFA).* ***Results:*** *An analysis of the relationship between primary and secondary stability of dental implants was conducted. It was found that the insertion torque directly influenced primary stability; however, over six years, secondary stability was compromised in 9 implants (6.1%), leading to their subsequent removal. The mean insertion torque for the removed implants was 39.5 N·cm, which exceeded the mean torque of the stable implants (35.6 N·cm) by 4.1 N·cm. Therefore, a high insertion torque may be a risk factor for impaired osseointegration in the long term.* ***Novelty:*** *There is still no consensus on how primary implant stability affects the process of osseointegration and which primary fixation values increase the risk of its disruption.*

INTRODUCTION

An analysis of the relationship between primary and secondary stability of dental implants was conducted. It was found that the insertion torque directly influenced primary stability; however, over six years, secondary stability was compromised in 9 implants (6.1%), leading to their subsequent removal. The mean insertion torque for the removed implants was 39.5 N·cm, which exceeded the mean torque of the stable implants (35.6 N·cm) by 4.1 N·cm. Therefore, a high insertion torque may be a risk factor for impaired osseointegration in the long term.

In modern dentistry, dental implantation is one of the most effective methods for prosthetic rehabilitation of edentulous patients. Strict adherence to protocols, well-established surgical techniques, and modern materials ensure reliable implant osseointegration and subsequent functional loading. One of the key conditions for the long-term function of a prosthetic construction is an adequate volume of bone tissue capable of providing sufficient resistance to implant loading [1].

The primary goal of dental implantology is achieving osseointegration of the endosseous implant. According to Brånemark, osseointegration is defined as "the direct structural and functional connection between organized bone tissue and the surface of the inserted implant" [2]. Successful osseointegration is the main indicator of clinical success in dental implant therapy. To achieve predictable osseointegration, titanium implants should be placed using atraumatic surgical techniques while avoiding

overheating of the bone bed. Ensuring primary implant stability and avoiding functional loading during the healing period of 3 to 6 months is essential [3].

The ultimate goal of treatment with dental implants is to improve patients' quality of life, restore normal functioning of the stomatognathic system, and achieve aesthetic results [4].

Two key factors determining the successful functioning of a dental implant are high primary stability and the absence of excessive pressure on the surrounding bone tissue [5], [6], [7]. Primary stability is provided by mechanical fixation, which depends on the implant's design and surface geometry. Studies show that, in the early stages, osseointegration depends on implant immobility: micromovements up to 150 μm do not disrupt the integration process, whereas exceeding this threshold can damage the blood clot and lead to fibrous tissue formation around the implant [8], [9].

During the initial stage of bone remodeling, osteoclast activity increases, temporarily reducing implant fixation. Increasing the insertion torque improves primary stability; however, excessive force may cause local ischemia and bone necrosis, negatively affecting long-term osseointegration [10], [11]. Primary stability also varies depending on the implant system selected and the macrostructure of its surface [12].

Secondary stability is determined by the mechanical and biological retention of bone tissue to the implant surface after the completion of osseointegration processes [13], [14]. Modern implantology shows a trend toward early functional loading, which shortens patient rehabilitation times. To enhance primary stability, bicortical implant placement is sometimes recommended, while implants placed together with bone augmentation or sinus-lift procedures can be stabilized using sinus-implant stabilizers [15]. In complex clinical conditions with immediate loading, intraoral welding systems are used, allowing sufficient stability for permanent prostheses within six weeks [16], [17].

If, due to anatomical features of the alveolar bone, sufficient contact area between the implant surface and the bone wall is not achieved, early functional loading is not recommended. At present, there is no consensus on whether high primary stability more often leads to successful osseointegration or which specific primary stability values may contribute to implant failure.

Study Aim:

To evaluate the clinical outcomes of dental implant application in the prosthetic rehabilitation of patients.

Objectives:

1. Using clinical methods, determine whether high primary stability always ensures successful osseointegration and how frequently suboptimal primary stability can still lead to osseointegration.
2. Based on the achievement of osseointegration, predict the long-term functional prognosis of implants.

RESEARCH METHOD

Between 2009 and 2015, a total of 149 dental implants were placed in 41 patients (mean age 49±7.6 years). The study was conducted following clinical protocol requirements and after obtaining informed consent. Patients were divided into two groups:

Group 1 consisted of 21 patients with 60 implants. At the initial stage of the study, the technical capability for resonance frequency analysis (RFA) was not available, so secondary stability was assessed using clinical methods: palpation, percussion, and manual examination. Primary stability was determined using dynamometry.

Group 2 included 20 patients with 89 implants. Dynamometry was used during implant placement, and at the second surgical stage, resonance frequency measurements were introduced using the Osstell device.

Patients in both groups underwent a standard comprehensive examination, including medical history collection, assessment of general somatic and psychosomatic status, evaluation of motivation for prosthetic rehabilitation with implants, and monitoring of oral hygiene compliance. Dental examinations included extraoral and intraoral inspection, and radiographic methods such as orthopantomography, radiovisiography, and computed tomography were applied. The degree of bone atrophy was assessed using measurements of plaster models.

Surgical interventions were performed following a standard two-stage protocol in accordance with implant manufacturers' recommendations. Postoperative control was carried out on days 1, 3, and 7, with suture removal on days 10–14. The second stage (placement of gingival formers) was performed three months after surgery for the mandible and 5–6 months for the maxilla. Subsequent follow-ups were conducted at 1, 3, 6, and 12 months.

Statistical analysis was performed using methods of variance statistics and correlation analysis with Microsoft Excel for Windows. Statistically significant differences were determined using Student's t-test at a significance level of $p<0.05$.

RESULT AND DISCUSSION

Over six years following implantation, 9 implants (6.1% of the total) were removed. In Group 1, 4 implants (6.7%) were removed, and in Group 2, 5 implants (5.6%) were removed. All removals occurred within the first 18 months after placement.

The mean insertion torque for all implants was 35.6 N·cm. Analysis showed that the insertion torque influenced primary stability, but no clear patterns were observed for secondary stability. Retrospective analysis revealed that the removed implants were placed with a mean torque 4.1 N·cm higher than the stable implants (39.7 N·cm). The overall range of insertion torque was 30–42 N·cm. No implant with a torque below 38 N·cm was removed, whereas all 9 removed implants had torques in the 38–42 N·cm range. A total of 27 implants were placed within this range, and nearly one-third of them were subsequently removed. This is likely related to individual variations in bone

structure and warrants further investigation. Therefore, a torque range of 38–41 N·cm can be considered a high-risk zone for implant failure.

The mean ISQ value measured by RFA was 62.5. No correlation was found between insertion torque and RFA measurements.

The use of a two-stage protocol did not cause complications and ensured osseointegration, provided that micromovements did not exceed 150 μm.

CONCLUSION

Fundamental Finding: Dynamometry of primary implant stability is an objective parameter that can be used to predict successful osseointegration and long-term functional performance. **Implication:** It is necessary to develop and implement early prosthetic protocols that account for implant micromobility, bone compression, and increased functional loading during the initial stages. **Limitation:** A relevant area of research is the expanded use of prosthetic rehabilitation with dental implants. **Future Research:** Further investigation and optimization of these approaches will help reduce complication risks and improve patient rehabilitation outcomes.

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