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ORIGINAL ARTICLE

The effects of subcrestal and supracrestal implant placement on primary stability parameters

ARTIGO ORIGINAL

Os efeitos da instalação dos implantes subcrestais e supracrestais nos parâmetros da estabilidade primária

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Abstract

Immediate implant placement is a common procedure, with implant stability often assessed using insertion torque (N·cm) and resonance frequency analysis (RFA). This study aimed to compare insertion torque and RFA values in simulated immediate implants placed at crestal, subcrestal, and supracrestal levels to evaluate how vertical implant positioning influences primary stability. Ninety Dentsply Sirona PrimeTaper™ implants were divided into three groups: Group 1 (4.2 × 13 mm placed 2mm of implant exposed), Group 2 (4.2 × 11 mm placed flush with the bone surface), and Group 3 (4.2 × 11 mm placed 2 mm below the crest). Osteotomies were performed in rigid polyurethane foam blocks simulating D2/D3 bone quality at a 45-degree angle. Implants were positioned to achieve intraosseous depths of 5 mm (Groups 1 and 3) and 3 mm (Group 2). Insertion torque was measured with a Dentsply Sirona EV Torque Wrench, and RFA values were obtained using an Osstell device. Data were analyzed using two-way ANOVA with Bonferroni post hoc testing. Torque values differed significantly between Groups 1 vs. 2 and Groups 2 vs. 3 ($p < 0.001$), but not between Groups 1 and 3. RFA values showed significant differences across all groups ($p < 0.001$). Subcrestal depth influenced insertion torque, while RFA values were affected by both subcrestal and supracrestal placement. These findings suggest that deeper implant placement enhances mechanical stability and underscores the importance of considering implant dimensions in treatment planning.

Keywords:
Dental Implants; Osseointegration; Resonance Frequency Analysis; Torque.

Resumo

A instalação imediata de implantes é um procedimento comum, sendo a estabilidade primária frequentemente avaliada por meio do torque de inserção (N·cm) e da análise de frequência de ressonância (AFR). Este estudo teve como objetivo comparar os valores de torque de inserção e AFR em implantes imediatos posicionados nos níveis crestal, subcrestal e supracrestal, a fim de avaliar como a posição vertical do implante influencia a estabilidade primária. Noventa implantes Dentsply Sirona PrimeTaper™ foram divididos em três grupos: Grupo 1 (4,2 × 13 mm do implante expostos), Grupo 2 (4,2 × 11 mm posicionados a 3 mm colocado nivelado com a superfície óssea) e Grupo 3 (4,2 × 11 mm colocado 2 mm abaixo da crista). As osteotomias foram realizadas em blocos de espuma de poliuretano rígida simulando osso tipo D2/D3, com inclinação de 45 graus. Os implantes foram posicionados para atingir profundidades intraósseas de 5 mm (Grupos 1 e 3) e 3 mm (Grupo 2). O torque de inserção foi medido com uma chave de torque Dentsply Sirona EV, e os valores de AFR foram obtidos com o dispositivo Osstell. Os dados foram analisados por meio de ANOVA de dois fatores com teste post hoc de Bonferroni. Os valores de torque diferiram significativamente entre os Grupos 1 e 2 e entre os Grupos 2 e 3 ($p < 0,001$), mas não entre os Grupos 1 e 3. Os valores de AFR apresentaram diferenças significativas entre todos os grupos ($p < 0,001$). A profundidade subcrestal influenciou o torque de inserção, enquanto os valores de AFR foram afetados tanto pelo posicionamento subcrestal quanto supracrestal. Esses achados sugerem que o posicionamento mais profundo do implante favorece a estabilidade mecânica, ressaltando a importância de considerar as dimensões do implante no planejamento do tratamento.

Palavras-chave:
Implantes Dentários; Osseointegração; Análise de Frequência de Ressonância; Torque.

Introduction

Immediate implant placement is often the preferred treatment following tooth extraction, particularly in the aesthetic zone. Benefits include reduced surgical interventions, preservation of soft tissue contours, shortened treatment time, and the potential for provisional restoration[1]. Although immediate placement has survival rates comparable to early or delayed protocols, its success depends on precise implant positioning, effective soft tissue management, and an appropriate surgical technique[2],[3].

Primary stability, defined as the mechanical engagement of the implant with the surrounding bone, is a prerequisite for successful osseointegration[4]. It refers to the absence of implant micromovement immediately after insertion and is influenced by factors such as bone quantity and quality, implant design, and surgical technique[5-7].Previous studies have emphasized that bone density, implant geometry, and macro/micro design features strongly affect the achievement of primary stability[8,9].In low-density bone, implants with multiple cutting threads may provide improved engagement and initial fixation[10]. Traditionally, primary stability was evaluated by insertion torque or percussion tests, where a ringing sound indicated good implant fixation[11]. More recently, resonance frequency analysis (RFA) has been introduced as a non-invasive, objective method to quantify implant stability[11, 12].

RFA provides information about the stiffness of the implant–bone interface by applying a lateral bending load, with values proportional to the frequency of vibration. The Implant Stability Quotient (ISQ) is a linear scale from 1 to 100 that corresponds to resonance frequencies ranging from 1000 Hz to 10,000 Hz[13]. The ISQ is easy to communicate and interpret clinically. For example, a 10-point ISQ increase (from 60 to 70) corresponds to a 50% reduction in micromobility[14, 15].

Since RFA is non-invasive, it can be used at any stage of treatment or follow-up without disrupting healing. It is especially useful in soft or medium-density bone, where small changes in implant stability are more detectable[16]. In dense bone, where initial stability is already high, the ISQ may not vary significantly despite continued osseointegration[17]. This supports its use in fresh extraction sockets, where it enables accurate assessment of implant stability without interfering with healing. Qabbani et al. (2017) found no long-term difference in RFA values between immediate and conventionally placed implants at 9 months, concluding that immediate implants can achieve both effective osseointegration and favorable esthetic outcomes[18].

The aim of this study was twofold: (1) to compare insertion torque and RFA values in implants placed at different intraosseous depths with identical extraosseous lengths, and[2] to compare these values in implants with varying extraosseous lengths but identical intraosseous depths

Materials and methods

This in vitro study evaluated the influence of subcrestal, crestal, and supracrestal implant positioning on primary implant stability.

Sample Preparation Rigid polyurethane foam blocks (Sawbones™, Pacific Research Laboratories, Vashon Island, WA, USA) with a density of 20 pounds per cubic foot (PCF) were used to simulate D2/D3 bone types (Figure 1). These blocks featured a cortical shell and a trabecular core, replicating the structural characteristics of human bone, as validated in prior mechanical studies.

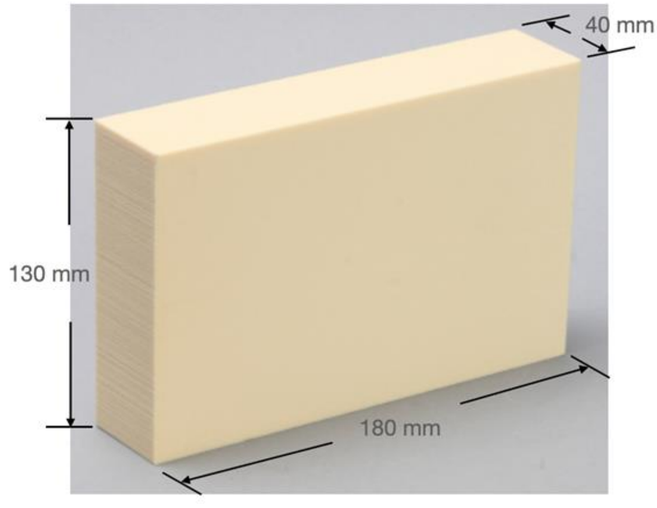

Figure 1: Solid Rigid Polyurethane Foam Bone Block.

Implant Protocol: Ninety Dentsply Sirona PrimeTaper™ EV implants (4.2 mm in diameter) were randomly assigned to three groups (n = 30 per group) (Table 1):

- Group 1 (Supracrestal): 4.2 × 13 mm implants placed with 2 mm of the implant exposed above the bone surface.
- Group 2 (Crestal): 4.2 × 11 mm implants placed flush with the bone surface.
- Group 3 (Subcrestal): 4.2 × 11 mm implants placed 2 mm below the bone surface.

Table 1. Specifications of implant groups with dimensions, placement depths, intraosseous engagement, and sample size

Group	Implant Size	Placement Depth	Intraosseous Depth	Extraosseous Length	N
Group 1 (Supracrestal)	4.2 × 13 mm	8 mm exposed (2 mm supracrestal)	5 mm	8 mm	30
Group 2 (Crestal)	4.2 × 11 mm	Flush with surface	3 mm	8 mm	30
Group 3 (Subcrestal)	4.2 × 11 mm	2 mm below surface	5 mm	6 mm	30

Implant lengths and insertion depths were chosen to ensure comparable intraosseous engagement between groups, thereby isolating the effects of extraosseous length on stability.

Surgical Procedure: Each group used a separate bone block (three blocks total). Site preparation followed the PrimeTaper™ protocol for very soft bone, using only drill #1 (1.9 mm) and drill #3 (2.95 mm) to simulate under-preparation and optimize primary stability. All osteotomies were performed at a 45-degree angle to simulate implant placement in fresh extraction sockets, where palatal or lingual positioning and angled engagement with socket walls are typical.

Two calibrated operators performed the osteotomies and implant placements. Calibration was standardized through a pilot phase involving five osteotomies per surgeon to ensure consistency.

For Groups 1 and 3, osteotomies were prepared to a depth of 5 mm. For Group 2, the depth was 3 mm. Implant insertion ensured a consistent intraosseous depth of 5 mm for Groups 1 and 3, and 3 mm for Group 2. The remaining implant length was extraosseous (Figure 2).

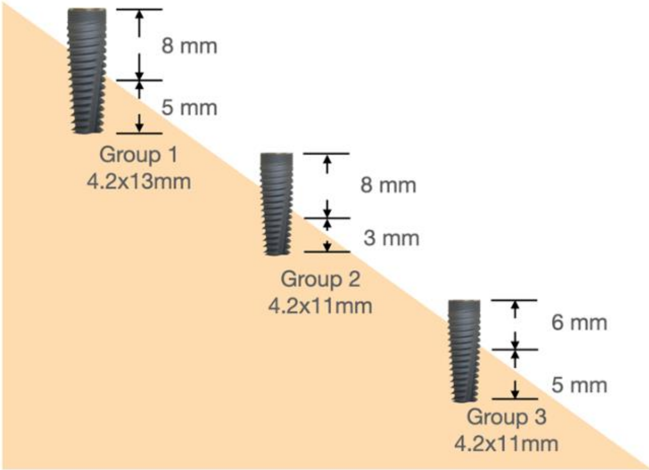

Figure 2: Illustration of the three implant groups with corresponding intraosseous and extraosseous lengths.

Stability Measurements

At the time of placement, insertion torque (IT) was measured using a Dentsply Sirona EV Torque Wrench. Resonance frequency analysis (RFA) was conducted in two perpendicular directions using the Osstell ISQ device.

Statistical Analysis

Mean values and standard deviations were recorded and summarized in Table 1. Statistical analysis was performed using SPSS software (IBM Corp., Armonk, NY, USA). A two-way ANOVA with Bonferroni post hoc testing was used to evaluate differences in IT and RFA values across the three groups. A significance level of $p < 0.05$ was considered statistically significant.

Results

A total of 90 implants were placed across three groups (n = 30 per group) to evaluate the effects of implant placement depth on primary stability as measured by insertion torque and resonance frequency analysis (RFA).

The mean insertion torque values for Groups 1, 2, and 3 were 37.17 ± 2.30 N·cm, 27.00 ± 2.81 N·cm, and 40.50 ± 1.76 N·cm, respectively. A two-way ANOVA with Bonferroni post hoc testing revealed statistically significant differences in insertion torque between Group 1 and Group 2 ($p < 0.001$), and between Group 2 and Group 3 ($p < 0.001$). No statistically significant difference was found between Group 1 and Group 3 ($p > 0.05$) (Figure 3).

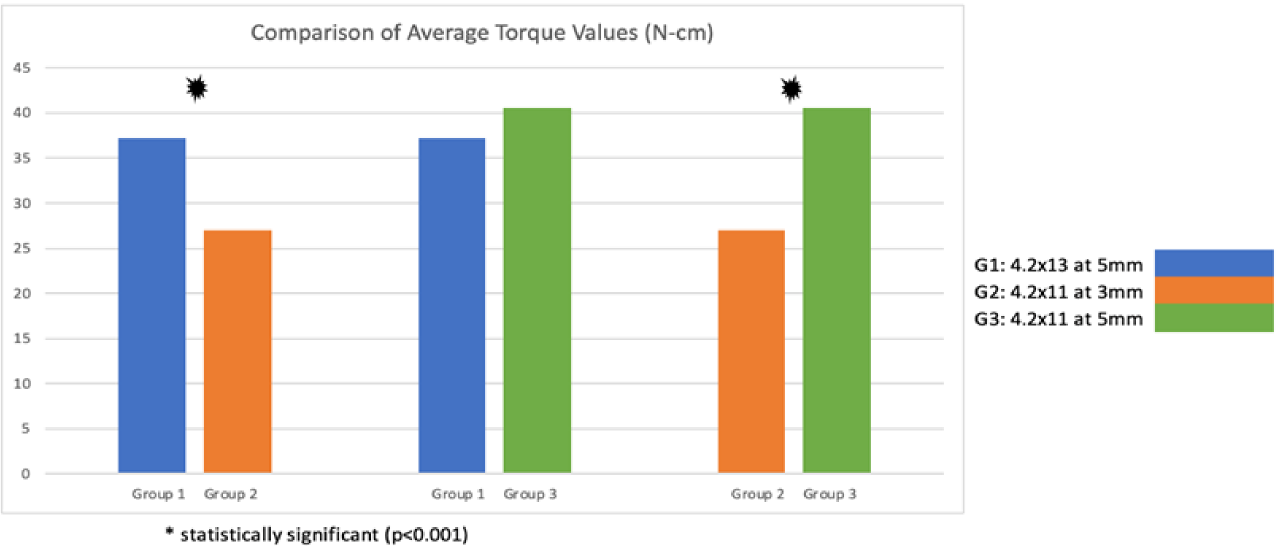

Figure 3: Comparison of mean insertion torque (N·cm) across the three groups. Significant differences observed between Group 1 vs. 2 and Group 2 vs. 3 ($p < 0.001$).

These results indicate that insertion torque was primarily influenced by intraosseous depth. Implants with greater bone engagement (Groups 1 and 3) demonstrated significantly higher insertion torque than those with shallower placement (Group B), regardless of total implant length.

The mean RFA values (ISQ) for Groups 1, 2, and 3 were 47.35 ± 2.02, 38.33 ± 1.92, and 52.66 ± 1.88, respectively. Statistically significant differences were observed among all group comparisons: Group 1 vs. Group 2 ($p < 0.001$), Group 1 vs. Group 3 ($p < 0.001$), and Group 2 vs. Group 3 ($p < 0.001$) (Figura 4).

Figure 4: Comparison of mean RFA values (ISQ) across groups. Significant differences were noted across all group comparisons (p< 0.001).

These findings suggest that both intraosseous and extraosseous (supracrestal) positioning affect RFA measurements. Implants with greater subcrestal depth and reduced supracrestal exposure (Group 3) exhibited the highest ISQ values, indicating superior implant–bone stiffness.

Discussion

This study evaluated the effects of different crestal positions and subcrestal depths on implant primary stability, using insertion torque and resonance frequency analysis (RFA) as outcome measures. Implants were placed at an angle to the bone blocks to simulate fresh extraction socket conditions, where the long axis of the implant is typically not perpendicular to the cortical surface. This angled positioning reflects the clinical scenario more accurately and contributes to the relevance of the findings[19].

The implant system used, PrimeTaper™, features a progressive taper with aggressive apical threads designed to enhance primary stability. These characteristics are especially advantageous in low-density bone. Previous studies have shown that both implant diameter and bone quality significantly affect primary stability, with longer implants often providing better mechanical engagement than wider ones in soft bone[11-23].

The results of this study showed that insertion torque was primarily influenced by intraosseous depth. When comparing Group 1 (13 mm implant with 5 mm intraosseous depth) to Group 2 (11 mm implant with 3 mm intraosseous depth), insertion torque was significantly higher in Group 1. A similar trend was observed between Groups 2 and 3 (both using 11 mm implants, but with different intraosseous depths), again favoring deeper placement (Group 3). However, there was no statistically significant difference in torque between Group 1 and Group 3, both of which shared the same intraosseous depth. This suggests that the subcrestal positioning of the implant plays a dominant role in achieving higher insertion torque, while the extraosseous (crestal) length has a negligible impact on this parameter.

In contrast, RFA values were affected by both intraosseous depth and crestal positioning. When comparing Group 1 and Group 2 (same crestal length, different depths), the deeper-placed implants (Group 1) showed higher RFA values. Similarly, comparing Group 1 and Group 3 (same depth, different crestal lengths), RFA was higher in Group 3, which had a shorter extraosseous portion. These results suggest that the exposed (supracrestal) portion of the implant may negatively influence the implant's stability as detected by RFA. The implant–bone interface becomes stiffer when more of the implant is embedded in bone and less is exposed, improving the ISQ score.

These findings align with literature suggesting that RFA is more sensitive than insertion torque in detecting subtle differences in stability, particularly in soft or medium-density bone.[15,16]. While insertion torque reflects initial mechanical engagement, RFA provides information on overall stiffness and fixation of the implant within the bone. It is also less affected by operator technique and insertion angle, making it a valuable tool for clinical monitoring.

This study has several limitations. First, it was conducted in vitro using polyurethane foam blocks, which, although validated to simulate bone density, cannot fully replicate the biological variability and healing dynamics of human bone. Second, only one implant system was tested. Additional studies using animal models and different implant designs would provide more comprehensive insights and improve generalizability.

Conclusions

Within the limitations of this in vitro study, implant
placement depth significantly influenced primary stability. Insertion torque was primarily affected by intraosseous depth, while resonance frequency analysis (RFA) was influenced by both intraosseous and supracrestal positioning. These findings emphasize the importance of considering vertical implant positioning, not only for initial mechanical stability but also for its potential implications in immediate loading protocols. Further clinical studies are recommended to validate these outcomes in vivo and explore their relevance across different bone types and implant systems.

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