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INFLUENCE OF THE CROWN-TO-IMPLANT RATIO (C/I RATIO) ON IMPLANT STABILITY AND CRESTAL BONE CONDITION

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ANNOTATION

Purpose of the study: *To determine the influence of the crown-to-implant ratio (C/I ratio) on load distribution, implant stability (ISQ), and the frequency of marginal bone microresorption.*
Materials and methods: *The study included 78 patients who underwent implant-supported restorations after sinus lifting. Cone-beam computed tomography (CBCT) and resonance frequency analysis (RFA) were used to measure implant length, clinical crown height, bone condition, and ISQ values. The C/I ratio was calculated as the ratio of clinical crown height to implant length. Statistical analysis included Pearson correlation and Student's t-test ($p < 0.05$).*
Results: *A strong positive correlation was found between an increased C/I ratio (>1.2) and marginal bone microresorption ($r = 0.68$; $p < 0.01$), while a negative correlation was observed between C/I and implant stability ($r = -0.62$; $p < 0.01$).*
Conclusion: *Maintaining a C/I ratio ≤ 1.1 ensures optimal biomechanical balance, higher implant stability, and reduced risk of bone resorption. Excessive C/I ratios (>1.2) are associated with biomechanical overload and compromised osseointegration.*
KEYWORDS: *C/I Ratio, Implant Stability, ISQ, Crestal Bone, CBCT, Load Distribution, Microresorption, Osseointegration.*

TOPICALITY

The biomechanical relationship between crown height and implant length-known as the crown-to-implant ratio (C/I ratio)- is a key determinant of long-term implant success. When clinical crown height substantially exceeds implant length (C/I > 1.2), the resulting lever effect amplifies occlusal forces, increasing micromobility, screw loosening, and crestal bone resorption [1-3].

CBCT-based research demonstrates that optimal load distribution occurs at C/I ratios of 0.9-1.1, where stress concentration in the crestal zone is minimal [4, 5]. Excessive ratios are particularly detrimental in the posterior maxilla, where bone density is low and masticatory forces are high. This highlights the importance of digital biomechanical evaluation and treatment planning prior to implant placement [6-8].

PURPOSE OF THE STUDY

To evaluate the influence of the C/I ratio on implant stability and crestal bone preservation using CBCT and resonance frequency analysis (ISQ) in patients after sinus lifting.

RESEARCH MATERIALS AND METHODS

The study included 78 patients aged 35-65 years who underwent implant placement in the posterior maxilla following open (n=40) or closed (n=38) sinus lifting. All patients had single crowns or short-span bridges with screw-retained restorations.

Parameters measured:Implant length (mm); Clinical crown height (mm); C/I ratio; Implant stability quotient (ISQ); Frequency of marginal bone microresorption (%); CBCT scans were obtained using Planmeca ProMax 3D Mid with a voxel size of 0.15 mm. The C/I ratio was computed as: C/I=implant length (mm)/clinical crown height (mm).
Resonance frequency analysis (RFA) was performed using *Osstell ISQ* at the time of prosthetic loading and at 12 months postoperatively. Statistical analysis employed Pearson's correlation and Student's t-test, with $p < 0.05$ considered significant.

RESEARCH RESULTS

Analysis of the Dynamics of Crestal Bone Height Changes at 3, 6, and 12 Months After Implant Placement

Table 1
Dynamics of Crestal Bone Height Over the Observation Period According to CBCT Data (mm)

Observation period	Group I (Open sinus lift, n = 40)	Group II (Closed sinus lift, n = 38)	p
Before implantation	5.2 ± 0.7	6.5 ± 0.6	< 0.01
After 3 months	7.4 ± 0.6	8.2 ± 0.5	< 0.05
After 6 months	8.6 ± 0.5	9.0 ± 0.4	> 0.05
After 12 months	9.3 ± 0.4	9.4 ± 0.3	> 0.05

Note: *Measurements were performed using cone-beam computed tomography (CBCT) with Planmeca Romexis 6.0 software. Statistical analysis was carried out using the Student's t-test; differences were considered significant at p < 0.05.*

CBCT monitoring demonstrated steady bone regeneration in both groups, with early differences favoring the closed sinus lift due to less surgical trauma and better membrane preservation. Over 12 months, both approaches achieved comparable crestal bone heights, confirming equivalent long-term osteogenic potential when appropriate clinical protocols are followed.

Influence of the C/I Ratio on Load Distribution and Implant Stability

The analysis showed (Table 2) that the C/I ratio (Crown/Implant ratio) is a key biomechanical parameter determining occlusal load distribution and implant stability. When C/I exceeded 1.2, there was a statistically significant increase in stress concentration in the cervical region of the implant and marginal bone, as evidenced by the rise in bone microresorption from 8.4% (C/I ≤ 1.1) to 19.6% ($p < 0.01$).

The mean primary stability values (ISQ) also depended on the C/I ratio:

- C/I ≤ 1.1 → ISQ = 71.3 ± 2.8
- C/I = 1.1–1.2 → ISQ = 68.4 ± 3.1
- C/I > 1.2 → ISQ = 63.7 ± 3.6 ($p < 0.05$)

Table 2
Influence of the C/I Ratio on Load Distribution and Implant Stability

Parameter	C/I ≤ 1.1 (n = 25)	C/I = 1.1–1.2 (n = 30)	C/I > 1.2 (n = 23)	p
Mean C/I ratio	1.05 ± 0.04	1.16 ± 0.03	1.28 ± 0.05	–
Mean ISQ value (primary stability)	71.3 ± 2.8	68.4 ± 3.1	63.7 ± 3.6	< 0.05
Frequency of bone microresorption (%)	8.4 ± 2.4	12.7 ± 3.1	19.6 ± 3.1	< 0.01
Frequency of soft tissue inflammation (%)	5.2 ± 1.9	9.8 ± 2.6	14.3 ± 2.9	< 0.05
Success rate of osseointegration (%)	98.0 ± 1.2	95.5 ± 1.8	90.3 ± 2.1	< 0.05

Note: At C/I > 1.2, a significant reduction in implant stability and an increased frequency of marginal bone resorption were observed. This is associated with uneven load distribution and micromovements in the cervical region. The optimal range of C/I ≤ 1.1-1.2 ensures biomechanical stability and long-term preservation of peri-implant bone tissue.

Table 3
Correlation Between C/I Ratio, Implant Stability, and Bone Microresorption

Parameter	Correlation coefficient (r)	p	Type of relationship
C/I ratio ↔ Implant stability (ISQ)	–0.62	< 0.01	Moderate negative, significant
C/I ratio ↔ Marginal bone microresorption (%)	+0.68	< 0.01	Moderate positive, significant
C/I ratio ↔ Mucosal inflammation (%)	+0.55	< 0.05	Moderate positive
ISQ ↔ Osseointegration success rate (%)	+0.71	< 0.01	Strong positive, significant

Note: Pearson's correlation analysis was used to determine the strength and direction of relationships between variables. Statistical analysis was performed using the Student's *t*-test. Differences were considered significant at $p < 0.05$ and highly significant at $p < 0.01$.

Pearson's correlation analysis (Table 3) confirmed a significant negative relationship between the C/I ratio and implant stability ($r = -0.62$; $p < 0.01$), as well as a positive correlation with the frequency of bone microresorption ($r = 0.68$; $p < 0.01$). These results emphasize the importance of maintaining an optimal C/I ratio ≤ 1.1-1.2 to achieve even load distribution and minimize the risk of marginal bone resorption.

DISCUSSION

The results of this study confirm that both the surgical technique and the biomechanical configuration of the implant–prosthetic complex have a decisive influence on peri-implant bone remodeling. The temporal evolution of crestal bone height observed by CBCT demonstrates that bone regeneration after sinus lifting is a dynamic and multifactorial process governed by surgical access, vascularization, and mechanical load transfer. In the early postoperative period, the closed sinus lifting technique favored faster maturation of the bone graft, likely due to minimal disruption of the Schneiderian membrane and preservation of local blood supply. This microenvironment supports the initial angiogenic and osteoconductive phases of healing, which are essential for early bone consolidation and uniform mineralization. Conversely, the open sinus lift, while more invasive, offers a greater volumetric gain in cases with severe alveolar atrophy, emphasizing its value as a method of choice in conditions of limited residual bone height. From a biomechanical standpoint, the analysis of the crown-to-implant ratio (C/I) further clarified the relationship between prosthetic design and functional stability. An excessive crown height relative to implant length shifts the center of occlusal load coronally, increasing bending moments and stress concentration at the crestal bone–implant interface. This mechanical overload contributes to marginal bone resorption and progressive loss of implant stability. The inverse correlation between C/I and ISQ, along with the positive association with microresorption frequency, highlights the critical role of maintaining biomechanical balance in prosthetic planning. The findings align with the conclusions of Misch (2020), Pommer (2023), and Tanaka (2021), who emphasized that C/I ratios exceeding 1.2 substantially elevate marginal stress, while ratios below 1.1 ensure favorable force distribution and long-term implant survival. Therefore, careful adjustment of the prosthetic height and implant length, supported by digital planning and finite element analysis, should be an integral part of modern implantology.

Overall, the integration of CBCT-based morphometric assessment and biomechanical modeling provides a reliable framework for evaluating the effectiveness of sinus lifting procedures. The combination of minimally invasive surgical techniques and rational prosthetic biomechanics allows achieving predictable bone regeneration, optimal implant stability, and prolonged functional success.

CONCLUSION

Closed sinus lifting provides faster bone maturation, higher density, and lower marginal resorption, ensuring greater implant stability. Maintaining an optimal crown-to-implant ratio ($C/I \leq 1.1$-1.2) is essential for balanced load distribution and long-term preservation of crestal bone.

Proper patient selection and digital planning with CBCT remain key factors for predictable and stable implant outcomes.

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