A Retrospective Study on the Treatment Outcome of Wide-Bodied Implants

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Purpose: This retrospective study documented the 5-year cumulative survival rate (CSR) of 5-mm-diameter wide-bodied implants in posterior jaws as related to identified risk factors and relative host bone site dimensions. **Materials and Methods:** Sixty-four wide-bodied implants placed consecutively in the posterior jaws of 43 patients were matched using several identified risk factors with 64 regular-diameter implants (3.75-mm or 4-mm diameter) placed in the posterior jaws of 25 of the same patients and 14 others. Life table analyses were undertaken to examine the difference in CSR between the groups. Multivariate Cox regression was conducted to assess the relationship between potential risk factors and overall CSR. **Results:** Ten of the wide-bodied implants failed (CSR 80.9%), while two of the regular-diameter implants failed (CSR 96.8%). The difference between the groups was statistically significant. Multivariate analysis demonstrated a significant predictive relationship between overall CSR and the ratio of implant volume to remaining bone volume. This suggests that relative determinants of critical bone volume to implant dimensions may need to be considered when planning implant surgery. **Conclusion:** Wide-bodied implants placed in the posterior jaw can suffer a significantly elevated risk of implant failure compared to regular-diameter implants. This susceptibility may relate to either implant design or the relative relationship of implant to host bone dimensions. *Int J Prosthodont 2004;17:52–58.*

Higher failure rates for implants placed in posterior jaw sites catalyzed development of the wide-bodied implant (WBI), with a 5-mm or greater diameter. It was presumed that wider-diameter implants would compensate for host site-specific deficits of either a quantitative or qualitative nature. Two studies[1,2] reported a better success rate for 4-mm-diameter implants in zone II (posterior to the mental foramina) for type III/IV bone[3] compared to 3.75-mm-diameter ones. Other relevant papers are presented in Table 1.[4–10] Short-term studies have described raw survival rates exceeding 91% for 5- and 6-mm-diameter machine-threaded titanium implants, most of which were in the posterior jaw.[4,5,7] However, the short observation periods make it diffcult to draw sound conclusions. In contrast, a relatively low cumulative survival rate (CSR) of 73.0% was reported among 5-mm-diameter threaded titanium Brånemark implants (Nobel Biocare) observed over 3 to 5 years in the posterior mandible.[8] In that study, a tendency was observed for an increased number of failures with decreased jaw volume. A 1-year report on outcomes in the posterior jaw found a similar CSR of 73.8% using 5-mm-diameter Brånemark implants with a wide-platform (WP) design.[9] Those authors commented that this was much lower than the CSR of more than 94% observed in an earlier study in the posterior jaw that included both regular-diameter implants (RDI) and 5-mm-diameter WBIs with a regular platform (RP) design.[11] Tawil et al[10] reported a similar high CSR of 96.9% for posterior 5-mm-diameter RP implants over 2 to 5 years of loading.

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Table 1 Short- and Medium-Term Results of Wide-Diameter Implants*

Study	Type of study	Period of follow-up	No. of patients	No. of implants	Failures	Raw survival (%)	Cumulative survival rate (%)
Graves et al[4]	Prospective	1–2 y	196	268	11	95.9	—
Bahat and Handelsman[5]	Prospective	3–26 mo	90	133	3	97.7	—
Aparicio and Orozco[6]	Retrospective	16–55 mo	45	94	9	90.4	Mx: 97.2 Md: 83.4
Renouard et al[7]	Retrospective	1 y	74	98	8	91.8	—
Ivanoff et al[8]	Retrospective	3–5 y	67	97	17	82.0	Mx: 86.3 Md: 73.0
Eckert et al[9]	Retrospective	0–734 d	63	85	19	77.6	73.8
Tawil et al[10]	Retrospective	2–5 y	60	97	3	96.9	96.9

*Graves et al[4] reported on 3i implants; all other studies involved Brånemark implants.
Mx = maxilla; Md = mandible.

Table 2 Distribution per Arch Location and Kennedy Classification According to Implant Diameter and Length

Diameter/type	Implant length (mm)	Maxilla		Mandible		Total
		I/II	III	I/II	III	
Regular diameter						
3.75-mm	< 10	1	1	1	3	6
3.75-mm	⩾ 10	11	6	10	23	50
4-mm	< 10	0	0	0	0	0
4-mm	⩾ 10	0	2	2	4	8
Subtotal		12	9	13	30	64
Wide diameter						
5-mm regular platform	8	0	0	1	0	1
5-mm regular platform	⩾ 10	6	1	1	5	13
5-mm wide platform	< 10	4	3	7	4	18
5-mm wide platform	⩾ 10	2	4	13	13	32
Subtotal		12	8	22	22	64

*I/II = distal extension, Kennedy Class I/II; III = tooth bounded, Kennedy Class III.

The objective in prescribing a WBI is bicortical stability and an increased area of interfacial contact. The major expectation is for an increase in implant treatment indications for Kennedy Class I and II partial edentulism. Other presumed indications include adjunctive site placements in edentulous patients and a better treatment outcome prognosis for posterior host bone site locations in the context of occlusal loading. However, it is possible that the increased diameter of a WBI may encroach upon the critical volume of host bone needed for osseointegration. Renouard and Riachi[12] proposed that WBIs require a 7-mm ridge width throughout their length. They noted that narrower host site dimensions would compromise bone support and risk implant failure. The possibility that a WBI osteotomy can distort the optimal ratio of cortical to cancellous bone so as to compromise the osseointegrated response demands investigation. Hence, the present preliminary study investigated possible determinants of treatment outcome differences between implant diameters placed in the posterior jaw. The hypothesis was that relative ratios between various host bone dimensions or between host bone dimensions and implant dimensions cannot predict CSRs for oral implants in the posterior jaw.

Materials and Methods

Charts were reviewed from all patients treated in the Implant Prosthodontic Unit at the University of Toronto with at least one implant in the posterior jaw. Implants involving bone augmentation were excluded. The WBI group comprised all 64 posterior WBIs (5-mm-diameter Brånemark implants with either the WP design or the original RP design) placed consecutively in 43 patients (mean age 50.7 years, range 23 to 77 years) and 46 partially edentulous arches (Table 2). A control group of 64 RDIs (either 3.75- or 4-mm-diameter Brånemark implants) in 39 patients (mean age 50.9 years, range 17 to 77 years; including 25 patients also in the WBI group) was selected from among all 352 RDIs placed in posterior zones. The RDIs were located in 44 partially edentulous arches (Table 2). To reduce the potential effect of identified risk factors, the control group was selected by matching each WBI with the first available RDI according to eight factors in the following order: prosthesis design (single implant vs splinted implants), patient (RDI in same patient as WBI vs not), arch (mandible vs maxilla), implant length, smoking history (smoker vs former smoker vs nonsmoker), opposing dentition (complete

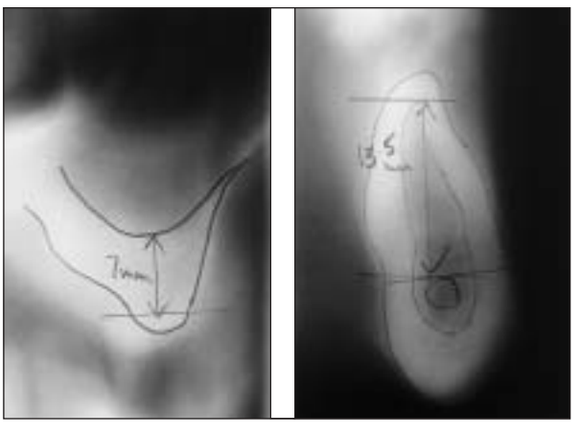

Fig 1 Sample of tomogram tracings for posterior edentulous maxilla *(left)* and mandible *(right)*.

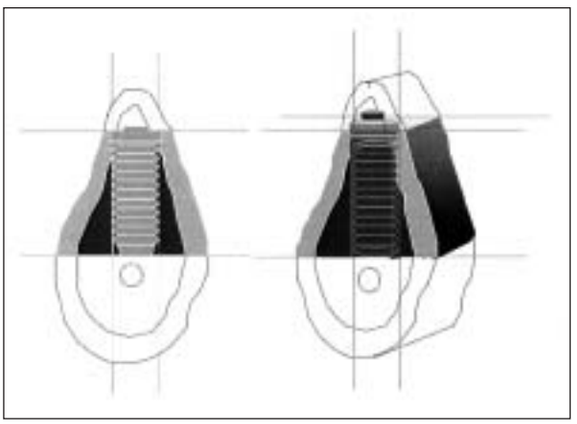

Fig 2 Bone area *(left)* and volume *(right)*.

denture vs removable partial denture or overdenture, vs natural dentition or fixed prosthesis), duration of loading, and Kennedy Class group (distal extension, Class I/II vs tooth bounded, Class III). Matching was permitted even if the RDI was placed prior to the WBI.

All patients were treated ad modum Brånemark as per existing surgical and prosthetic protocols.[13] Existing removable dentures were relined and worn no sooner than 2 weeks after implant placement (stage one). Implants were normally uncovered (stage two) at least 6 months after stage one. Regular, usually annual, follow-up visits were scheduled after prosthesis placement to assess treatment outcomes according to established success criteria indicated by implant immobility and a lack of pain, pathology, radiolucency, and bone loss associated with each implant.[14,15] Mobile implants were considered failures and were removed. The dependent outcome was overall CSR based on the probability of success at the midpoint of each time interval from implant placement to implant failure.

Independent Variables

Nominal and ordinal variables included the following: implant group (RDI vs WBI), gender, arch, side, tooth type (premolar vs molar), Kennedy classification (distal extension, Class I/II vs tooth bounded, Class III), prosthesis design (single vs splinted implants), opposing dentition (complete denture vs removable partial denture or overdenture, vs natural dentition or fixed prosthesis), systemic health (healthy vs diabetes mellitus vs arthritis vs other illnesses), smoking history (smoker vs former smoker vs nonsmoker), smoking history recoded (smoker vs current nonsmoker), surgeon (as five different surgeons with most frequent surgery and two others with less-frequent surgery), surgeon recoded (using five dummy variables), implant length recoded (< 10 mm vs 10 mm vs > 10 mm up to 13 mm vs ≥ 13 mm), implant type (3.75-mm vs 4-mm vs 5-mm RP vs 5-mm WP), Fédération Dentaire Internationale tooth position recoded (with 7 and 8 positions recoded as 7), bone quality (Lekholm-Zarb classification[3]), number of implants in the prosthesis, and number of occlusal units in the prosthesis. Continuous variables included the following: implant length, implant width, age at stage-one surgery, healing period (from stage one to loading), number of years of edentulism, and various relative determinants of host bone dimensions and ratios between the host bone dimensions and implant dimensions.

To develop relative determinant variables, the master cast and a standardized postoperative panoramic radiograph were used to estimate the position and angulation of each implant. From this, a specific cross-sectional image was selected from the preoperative tomogram series to determine host bone and implant dimensions for each implant site (Fig 1). Each selection was superimposed with a scale-corrected implant shape with consideration of the estimated implant angulation, after Dempster et al.[16] The implant shape and the cortical and cancellous outlines were traced on two occasions at least 2 weeks apart, and the tracings were digitized and measured using the software SigmaScan Pro 5.0 (SPSS) to determine the cross-sectional area occupied by cortical and cancellous bone and by the implant. The mean area of the two tracings was used to develop several relative determinants of each host bone site related to the host bone area and host bone volume (Fig 2).

Relative determinants included the following: bone area (mm^2), cortical bone area (mm^2), cancellous

Table 3 Cumulative Implant Survival in Wide-Bodied Implant (WBI) and Regular-Diameter Implant (RDI) Groups

Time period	Implants entering period	Patient death or migration	Implants exposed to risk	Implant failures	Interval survival rate (%)	Cumulative survival rate (%)
WBI group						
Placement–loading	64	1	61.5	7	88.6	88.6
Loading–1 y	52	2	42.5	2	95.3	84.5
1–2 y	31	0	23.5	1	95.7	80.9
2–3 y	15	0	12.5	0	100.0	80.9
3–4 y	10	0	8.5	0	100.0	80.9
4–5 y	7	0	3.5	0	100.0	80.9
RDI group						
Placement–loading	64	0	62.5	2	96.8	96.8
Loading–1 y	59	4	48.5	0	100.0	96.8
1–2 y	38	0	30.5	0	100.0	96.8
2–3 y	23	0	18.0	0	100.0	96.8
3–4 y	13	0	10.0	0	100.0	96.8
4–5 y	7	0	5.0	0	100.0	96.8
5–6 y	3	0	3.0	0	100.0	96.8
6–7 y	3	0	1.5	0	100.0	96.8

bone area (mm^2), cortical bone percent (cortical bone/bone area percent), cancellous bone percent (cancellous bone area/bone area percent), implant area (mm^2) (implant length × implant width), implant area/bone area percent, implant area/cancellous bone area percent, mean bone width (mm) (bone area/implant length), implant width/mean bone width percent, remaining bone area (mm^2) (bone area – implant area), remaining cortical bone area (mm^2), remaining cancellous bone area (mm^2), remaining cortical bone percent (remaining cortical bone area/remaining bone area percent), remaining cancellous bone percent (remaining cancellous bone area/remaining bone area percent), remaining cancellous area/bone area percent, remaining cancellous bone area/cancellous bone area percent, implant area/remaining bone area percent, bone volume (mm^3) (bone area × 5 mm as a standardized mesiodistal thickness of available bone in which the preparation was made), implant volume (mm^3) ($\pi \times {}^1/_2$ implant width^2 × implant length), implant volume/bone volume percent, implant volume/cancellous bone volume percent, remaining bone volume (mm^3) (bone volume – implant volume), and implant volume/remaining bone volume percent. The mean axial bone area (mm^2) (bone volume/implant length) was also calculated for each implant site.

Statistical Analysis

The difference in CSR outcomes between the groups was examined for statistical significance ($P < .05$) with the life table survival function of SPSS (SPSS), specifically using the Wilcoxon statistic. Multivariate analyses of the relationship between the various independent variables and overall CSR were conducted using the Cox regression function of SPSS software as appropriate for the multivariate analysis of CSR outcomes where follow-up periods vary.[17,18] The analyses were conducted using forward likelihood ratio $P < .05$ for entry of variables into regression models and $P < .10$ for removal of variables. The Cox regression models were associated with a hazard ratio estimate for each significant variable, effectively representing the relative risk of implant failure. Nominal and ordinal variables were included in the multivariate analysis if preliminary analysis demonstrated at least a statistically borderline significant ($P < .15$) Wilcoxon statistic association with overall CSR using the life table survival function of SPSS. Continuous variables were included in the multivariate analysis if preliminary analysis demonstrated at least an independent statistically borderline significance ($P < .15$). The group, implant type, and implant width variables were conceptually and mathematically associated with each other so each was included in the regression testing separately.

Results

During the study, 10 of 64 WBIs and 2 of 64 RDIs failed (Table 3). By the conclusion of the study, prosthesis fabrication had not been completed for one osseointegrated 5-mm-diameter WP implant because an adjacent implant had failed, and for one osseointegrated 5-mm-diameter RP implant because the patient moved out of contact after stage-two surgery. Follow-up examinations were conducted for up to 5 years after loading among the WBI group and up to 7 years after loading among the RDI group. During the first year, another patient had moved out of contact, removing two 5-mm-diameter RP implants and four

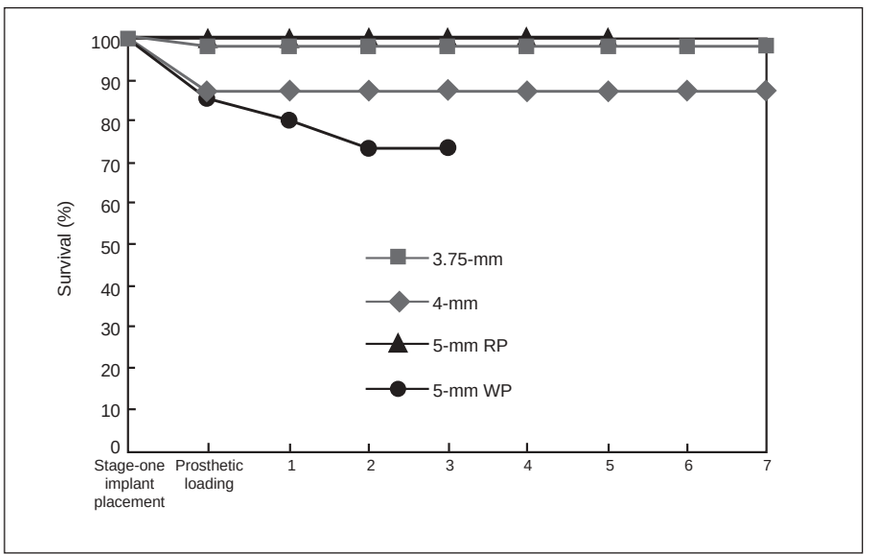

Fig 3 Cumulative implant survival for implant type groups. *RP* = regular platform; *WP* = wide platform; significant difference ($P < .05$) only between 3.75-mm-diameter and 5-mm-diameter WP groups with Wilcoxon statistic.

Table 4 Multivariate Associations with Overall Cumulative Survival Rate of Implants

Variable	*P* value	B (regression) coefficient)	Exp(B) (hazard ratio)
Implant volume/remaining bone volume %	.034	0.031	1.03
Implant volume/bone volume %	.038	0.077	1.08
Remaining cancellous area/cancellous area %	.043	–0.044	0.96
Group (regular vs wide)	.032	1.665	5.29
Implant type (3.75-mm, 4-mm, 5-mm RP, 5-mm WP)	.016*	2.543	12.72
Implant width (diameter)	.028	1.441	4.22

*Applies only to pairwise comparison between 3.75- and 5-mm-diameter WP implants.
RP = regular platform; WP = wide platform.

3.75-mm-diameter implants from further follow-up. By the most recent examination, three other osseointegrated implants in both groups had not yet been recalled for assessment. The overall CSR of the WBIs was 80.9%, compared to 96.8% for the RDIs (Table 3). The difference between the groups was statistically significant ($P < .05$). Preliminary radiographic analysis suggested that the mean rate of bone resorption proximal to the implants was less than 0.1 mm/year in both groups.

Although the WBI group suffered a significantly lower success rate compared to the RDI group, the 5-mm-diameter WP implants had a much lower CSR of 73.7%, compared to an overall CSR of 100% among the 5-mm RP implants (Fig 3). In the RDI group, one implant failure occurred among the 3.75-mm-diameter implants, contributing to a CSR of 98.2%, compared to a CSR of 87.5% among the 4-mm-diameter implants. Although it was not part of the hypothesis testing, it was found that the only statistically significant difference between the survival curves of these four subgroups, again using the Wilcoxon statistic, was between the 5-mm-diameter WP group and the 3.75-mm-diameter group.

Preliminary statistical analysis demonstrated significant independent associations between overall CSR and several dependent variables, including group, implant type, surgeon, implant length, implant width, remaining cancellous bone area/cancellous bone area percent, implant volume/bone volume percent, and implant volume/remaining bone volume percent.

The Cox regression analysis demonstrated a significant predictive relationship between overall CSR and only one variable, implant volume/remaining bone volume percent (Table 4). The risk of overall implant failure was increased by approximately 3% with each percentage-point increase in implant volume/remaining bone volume percent. Excluding this

variable in the analysis yielded significance of the next most significant relative determinant, implant volume/bone volume percent. Likewise, when this variable was excluded from the testing, the next most significant relative determinant, remaining cancellous bone area/cancellous bone area percent, was the only significant variable. Excluding all relative determinants from the regression testing yielded implant type as the only significant variable. When this variable was dropped in favor of either the group or implant width variables, each one remained as the only significant variable in the model. The risk of overall implant failure was increased approximately 4 times for every 1-mm increase in implant width (diameter), was increased approximately 5 times among WBIs compared to RDIs, and was increased nearly 13 times among 5-mm-diameter WBIs compared to 3.75-mm-diameter implants.

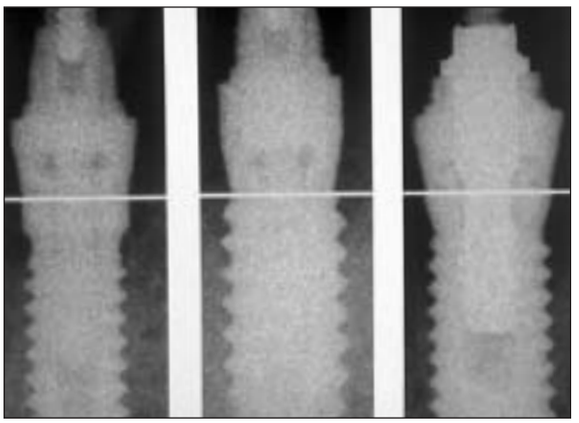

Fig 4 Radiogram of 3.75-mm-diameter implant *(left)*, 5-mm-diameter regular-platform (RP) implant *(center)*, and 5-mm-diameter wide-platform (WP) implant *(right). Horizontal line* = abutment-implant junction. Threads of 5-mm-diameter RP implant are deeper and have wider pitch than those of regular-diameter implant and 5-mm-diameter WP implant.

Discussion

The predictability of posterior RDIs has recently been reinforced by a study reporting a CSR of 94% over a period up to 10 years.[19] However, given the very different treatment outcomes reported previously on WP WBIs compared to RP WBIs or 3.75-mm-diameter implants, the current analysis makes the observed failure pattern of the 5-mm-diameter WP implants more serious than that seen for previous implant designs. Notably, there were no failures among the 5-mm-diameter RP implants in the current study. However, only 14 such implants were studied, so the observed lack of statistical difference in CSR between the WP and RP WBI groups may not have been scientifically sound. As in other studies, the precise cause of increased failure of the 5-mm-diameter WP implants in the present study remains unknown. Differences in the surgeon's experience with RDIs compared to WBIs could have played a role. It may be that WP design differences impaired initial implant stability, compromising the healing response. For example, the threads are deeper and have a wider pitch with the RP WBIs compared to those found on RDIs and WP WBIs (Fig 4). The absence of a smooth collar at the level of the hexagonal head on the RP WBIs may also have avoided overheating cortical bone at the time of countersink preparation for the WP shoulder. Theoretically, the WP design may also be more susceptible to inadvertent transmucosal loading during the healing period because of the larger surface area available compared to the RP design.

Our analysis implicated several relative determinants of bone and implant dimensions as potential risk factors for oral implant failure in the posterior jaw. The ratio of implant volume to remaining bone volume was the most significant predictor of implant failure in this study. This finding supports previous hypotheses that some aspect of critical bone volume may be important in implant survival, and specifically that the failure risk of 5-mm-diameter WP implants may be exaggerated by encroaching upon the volume of bone that is critical for implant survival.[9] Since most of the bone removed during implant surgery is cancellous bone, we propose that the concept of a critical bone volume may relate particularly to cancellous bone volume. In this study, the mean ratio of remaining cancellous bone area to cancellous bone area was 20.1% ± 13.6% among the successful implants and only 12.9% ± 11.7% among the failed implants. We speculate that the removal of cancellous bone during placement of the wide-diameter implants may have tended to encroach upon a critical relative volume of cancellous bone needed for normal bone metabolism and remodeling in achieving and maintaining osseointegration. This hypothesis may explain the higher rate of implant failure we observed among WBIs. However, we also found that posterior oral implant failure was significantly predicted by both the relative ratio of implant volume (the volume of bone removed at implant placement) to remaining bone volume and the relative ratio of implant volume to bone volume. This suggests that relative volume of total bone (cancellous and cortical) removed at implant surgery is at least equally implicated in the osseointegration response of the posterior jaw.

The true relationship between implant and host bone site dimensions was simulated in this study

using preoperative tomograms. Consequently, estimates of the dimensional relationships may have included minor inaccuracy. However, in our view, the results were hampered primarily by limited numbers of patients and implants, and by a shorter follow-up period among WBIs compared to RDIs. This resulted in selecting RDIs and WBIs with significantly different implant lengths and number of molar sites. The mean length of the WBIs (10.1 ± 1.8 mm) was significantly shorter than that of the RDIs (11.4 ± 1.9 mm), presumably because of a lack of bone height in the WBI sites. There were also significantly more molar sites in the WBI group (n = 55) compared to the RDI group (n = 23). Both shorter implants and molar sites tended to show higher failure rates, leaving group comparisons potentially biased by implant length and tooth type. However, neither implant length nor tooth type variables were significant in the regression testing.

Despite these design shortcomings, we believe that the present study offers a reasonable suggestion that host bone site dimensions may influence the CSR of implants in the posterior jaw. It appears, therefore, that it would be prudent to limit the specific choice of a WBI to those situations with ample buccolingual jawbone dimensions. At the very least, the routine prescription of a WBI for the posterior zones on the grounds of reduced vertical bone height requires more careful scrutiny. Multiple-variable analyses with long-term follow-up on larger patient groups should be undertaken to confirm this hypothesis.

WBIs placed in the posterior jaw are vulnerable to a significantly elevated risk of implant failure when compared to RDIs. This observation may relate not only to specific implant design features, but also to the relative relationship of implant to host bone dimensions.

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