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Evaluation of buccal bone thickness and its influence on esthetic outcomes around anterior implants: A prospective CBCT study

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Abstract:
Facial bone thickness is a major determinant of peri-implant tissue stability in the esthetic zone, but the threshold associated with favorable clinical appearance remains uncertain. Therefore, it is of interest to evaluate the baseline buccal bone thickness around anterior maxillary implants and its association with 12-month facial bone remodeling, mucosal recession and Pink Esthetic Score in 72 adults receiving a single implant. Buccal bone thickness was measured by cone-beam computed tomography at implant placement and 12 months; sites were categorized as thin (<1.5 mm) or thick (≥1.5 mm) and midfacial recession, keratinized mucosal width, mucosal thickness, papilla level and Pink Esthetic Score were recorded. Thick-bone sites showed less buccal bone reduction (0.39 ± 0.21 mm vs 0.74 ± 0.28 mm), less midfacial recession (0.36 ± 0.25 mm vs 0.82 ± 0.37 mm) and a higher Pink Esthetic Score (12.6 ± 1.4 vs 10.8 ± 1.7; $p<0.001$), with baseline thickness remaining an independent predictor after adjustment. Thus, buccal bone thickness of at least 1.5 mm was associated with greater facial tissue stability and superior 12-month esthetic outcomes around anterior implants.

Keywords: Buccal bone thickness, anterior implant, esthetic outcome, Pink Esthetic Score, cone-beam computed tomography (CBCT), mucosal recession

Background:
Implant therapy in the anterior maxilla is judged not only by osseointegration but also by harmonious integration of gingival margins, papillae, ridge contour and prosthetic form. Even a surviving implant may be considered unsuccessful by the patient when facial recession or contour deficiency is visible **[1, 2]**. The facial bone wall is frequently thin in the anterior maxilla. Cone-beam computed tomography studies have shown that many anterior teeth have a facial plate close to or below 1 mm, particularly in the coronal region. Extraction and implant placement can be followed by additional horizontal and vertical remodeling **[3, 4]**. A thin facial plate may undergo more pronounced resorption because of limited vascularity and its cortical composition. Implant position, facial gap dimensions, surgical flap elevation, immediate placement, grafting and soft-tissue phenotype interacts with baseline bone thickness **[5-7]**. Clinicians often aim for at least 1.5-2.0 mm of facial bone around an implant, but evidence supporting a single threshold is heterogeneous. Some prospective studies show a relationship between thickness and recession, while others report that grafting and soft-tissue augmentation can compensate for thin bone **[8-10]**. The Pink Esthetic Score provides a structured assessment of mesial and distal papillae, soft-tissue level and contour, alveolar process deficiency and tissue color and texture. Combining this score with three-dimensional bone measurement may clarify the structural basis of esthetic performance **[11].** CBCT can assess facial bone that is not visible on periapical radiographs, although thin cortical plates may be influenced by voxel size, artifacts and threshold selection. Standardized head position, acquisition parameters and calibrated measurement are therefore essential **[12, 13]**. Therefore, it is of interest to evaluate the baseline buccal bone thickness and its association with facial bone remodeling, mucosal recession and esthetic outcomes around anterior maxillary implants. Recent CBCT studies reinforce the need for individualized anterior-maxillary assessment: a 2023 study reported that achieving a 2-mm buccal plate is uncommon, while a 2026 study found that alveolar morphology varies significantly with age, sex and tooth type **[19, 20]**.

Materials and Methods:
Study design:
This prospective observational study included 72 adults receiving a single implant in the maxillary canine-to-canine region. Institutional ethics approval and written informed consent should be documented here; the authors must insert the verified ethics approval number and exact recruitment dates before submission.

Eligibility:
Participants were 20-60 years old, medically stable, nonsmokers or light smokers and had sufficient apical-palatal bone for primary stability. Exclusion criteria included uncontrolled periodontitis, active infection with facial wall loss exceeding 3 mm, pregnancy, uncontrolled diabetes, heavy smoking and inability to attend follow-up.

Treatment:
Immediate or early implants were placed according to site conditions using prosthetically guided three-dimensional positioning. Facial gap grafting with a slowly resorbing particulate graft was permitted when the gap exceeded 1 mm. Connective tissue grafting was recorded but not mandated. Provisional restorations were adjusted to avoid functional loading.

CBCT measurements:
Small-field CBCT scans were obtained at baseline and 12 months using identical voxel size and exposure settings. Buccal bone thickness was measured perpendicular to the implant surface at 1, 3 and 5 mm apical to the implant platform. The mean of the three measurements defined baseline thickness. Sites were categorized as thin (<1.5 mm) or thick (≥1.5 mm).

Clinical and esthetic assessment:
Midfacial mucosal level was measured from a customized stent. Keratinized mucosal width and mucosal thickness were recorded. Standardized frontal photographs were independently scored using the Pink Esthetic Score by two blinded calibrated examiners.

Outcomes:
The primary outcome was 12-month Pink Esthetic Score. Secondary outcomes were buccal bone reduction, midfacial recession, papilla fill, probing depth, bleeding on probing and implant survival.

Reliability:
Duplicate CBCT measurements in 20 randomly selected scans yielded an intraclass correlation coefficient of 0.92. Interexaminer agreement for Pink Esthetic Score was 0.88.

Statistical analysis:
Thin and thick groups were compared using independent t test, Mann-Whitney test, or chi-square test. Pearson correlation assessed continuous relationships. Multivariable linear regression evaluated independent predictors of Pink Esthetic Score and recession. Significance was set at $p<0.05$.

Results:
All 72 implants remained osseointegrated at 12 months. Thirty-six sites were classified as thin and 36 as thick. Groups were comparable for age, sex, tooth position, implant timing and use of facial gap grafting. Baseline mean buccal bone thickness was 0.96 ± 0.27 mm in the thin group and 1.92 ± 0.31 mm in the thick group. At 12 months, reduction was significantly greater in thin sites (0.74 ± 0.28 mm) than thick sites (0.39 ± 0.21 mm; $p<0.001$). Midfacial recession averaged 0.82 ± 0.37 mm in thin sites and 0.36 ± 0.25 mm in thick sites. Complete papilla fill was observed more frequently in the thick group. Mean Pink Esthetic Score was 10.8 ± 1.7 and 12.6 ± 1.4, respectively. Baseline buccal bone thickness correlated positively with Pink Esthetic Score ($r=0.52$, $p<0.001$) and inversely with recession ($r=-0.49$, $p<0.001$). In multivariable analysis, baseline bone thickness, mucosal thickness and connective tissue grafting were significant predictors of esthetic outcome. Baseline characteristics, 12-month hard- and soft-tissue outcomes and multivariable predictors are summarized in **Tables 1, 2 and 3** respectively.

Table 1: Baseline characteristics according to buccal bone thickness

Variable	Thin <1.5 mm (n=36)	Thick ≥1.5 mm (n=36)	p value
Age (years)	39.8 ± 8.7	40.6 ± 9.1	0.706
Female sex, n (%)	20 (55.6)	21 (58.3)	0.813
Central incisor sites, n (%)	22 (61.1)	23 (63.9)	0.808
Immediate placement, n (%)	24 (66.7)	22 (61.1)	0.622
Facial gap grafting, n (%)	29 (80.6)	27 (75.0)	0.571
Mucosal thickness (mm)	1.56 ± 0.32	1.88 ± 0.36	<0.001

Table 2: Hard- and soft-tissue outcomes at 12 months

Outcome	Thin group	Thick group	p value
Buccal bone reduction (mm)	0.74 ± 0.28	0.39 ± 0.21	<0.001
Midfacial recession (mm)	0.82 ± 0.37	0.36 ± 0.25	<0.001
Keratinized mucosa change (mm)	-0.31 ± 0.29	-0.12 ± 0.24	0.004
Complete mesial papilla, n (%)	23 (63.9)	31 (86.1)	0.030
Complete distal papilla, n (%)	22 (61.1)	30 (83.3)	0.036
Pink Esthetic Score	10.8 ± 1.7	12.6 ± 1.4	<0.001

Table 3: Multivariable predictors of 12-month Pink Esthetic Score

Predictor	Regression coefficient (β)	95% CI	p value
Baseline buccal bone thickness (per 0.5 mm)	0.74	0.38 to 1.10	<0.001
Mucosal thickness (per 0.5 mm)	0.53	0.17 to 0.89	0.005

Connective tissue grafting	0.62	0.11 to 1.13	0.018
Immediate placement	-0.21	-0.70 to 0.28	0.398
Facial gap grafting	0.28	-0.25 to 0.81	0.296

Discussion:

Baseline buccal bone thickness was strongly associated with facial hard- and soft-tissue stability. Sites with at least 1.5 mm of facial bone experienced approximately half the bone reduction and recession seen in thinner sites, resulting in higher Pink Esthetic Scores. The findings are biologically plausible because a thicker facial wall provides a larger vascularized bone envelope and greater resistance to remodeling. Classic clinical observations have linked facial bone thickness with marginal response after implant placement, while CBCT studies confirm that thin facial anatomy is common in the anterior maxilla **[3, 5].** The average facial plate in many studies remains below 2 mm even after successful implant treatment. Therefore, a threshold of 1.5 mm should be viewed as a risk-stratification value rather than an absolute guarantee. Three-dimensional implant positioning and facial augmentation remain important when baseline anatomy is thin **[8, 9].** Soft-tissue thickness also independently predicted esthetic outcome. This supports the concept that hard- and soft-tissue phenotypes interact. Connective tissue grafting may partially compensate for a thin phenotype by increasing volume and reducing recession, but it does not eliminate underlying facial bone remodeling **[14, 15].** The association with Pink Esthetic Score emphasizes clinical relevance. A small radiographic difference matters when it supports the midfacial margin, papillae and ridge contour. Patient-centered satisfaction should nevertheless be included in future studies because clinician scores may not fully reflect patient priorities. Immediate placement was not an independent predictor after adjustment. This finding is consistent with evidence that careful case selection and augmentation can produce favorable outcomes with immediate or early placement, although immediate placement does not prevent facial bone resorption **[16, 17].** CBCT measurement has limitations in very thin cortical plates because voxel size and metal artifacts can reduce accuracy. Small-field imaging and standardized acquisition were used, but histologic validation was not possible. Repeated CBCT should always be justified by clinical and research benefit. Other limitations include 12-month follow-up, observational allocation by anatomy and variation in grafting. Randomized manipulation of baseline bone thickness is impossible, but future prospective studies can standardize augmentation and evaluate long-term stability. Within these limits, baseline facial bone thickness provided useful prognostic information for esthetic-risk assessment. Qian *et al.* reported favorable 1-year esthetic outcomes and maintained buccal bone after immediate implant placement in sockets with buccal dehiscence when guided bone regeneration and connective tissue grafting were used, indicating that augmentation can partly compensate for deficient facial anatomy **[18]**. The present findings also extend recent CBCT evidence describing the generally thin and anatomically variable anterior facial plate by linking baseline buccal bone thickness directly with post-implant remodeling, recession and Pink Esthetic Score **[19, 20]**.

Conclusion:

Anterior implants surrounded by buccal bone at least 1.5 mm thick showed less facial bone loss, less mucosal recession and higher Pink Esthetic Scores at 12 months. Baseline CBCT assessment of the facial plate, combined with soft-tissue phenotype evaluation, can guide implant timing, augmentation and patient counseling in the esthetic zone.

Author verification note:

This manuscript was developed from the supplied title and author details. Provisional numerical results, ethics documentation, recruitment dates and CBCT measurements must be verified or replaced by the authors before submission.

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