Bone Graft Healing in Reconstruction of Maxillary Atrophy

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ABSTRACT

Purpose: Evaluate correlations between volume change for iliac crest bone grafts in maxillary reconstruction (graft volume change [GVC]) and bone mineral density (BMD), bone volume fraction (BVF), hematologic bone metabolic factors (I), and identify indicators of implant failure (II).

Material and Methods: Forty-six consecutive patients had their edentulous atrophic maxilla reconstructed with free autogenous bone grafts from anterior iliac crest. Endosteal implants were placed 6 months after graft healing. Computer tomography was performed after 3 weeks and 6 months after grafting. Bone biopsies were taken from the internal table of donor site for calculation (BVF), and blood samples were collected. Implant stability was measured at placement with resonance frequency analysis and expressed as implant stability quotient (ISQ). Implant failure was registered.

Results: GVC in onlay bone graft was 37%. The BVF in iliac crest biopsies was 32%. Serum-IGFBP3 differed with 79% of the samples over normal range. Fifteen patients had one or more implant failures prior to loading (early failures). Forty-two patients were followed for a minimum of 3 years after implant loading and, in addition, 6/42 patients had one or more implants removed during the follow-up (late failures). GVC correlated to decreased BMD of lumbar vertebrae L2-L4 (Kruskal–Wallis test, $p = .017$). No correlation was found between GVC and hematologic factors (Pearson correlation test) or between GVC and BVF (Kruskal–Wallis test). No correlation was found between ISQ and GVC (Pearson correlation test, $p = .865$). The association between implant failures and the described factors were evaluated, and no significant correlations were found (unconditional logistic regression).

Conclusion: Onlay bone grafts decrease 37% during initial healing period, which correlate to BMD of lumbar vertebrae L2-L4. No other evaluated parameters could explain GVC. The evaluated factors could not explain implant failure.

KEY WORDS: autogenous bone graft, bone metabolic factors, bone mineral density, donor bone quality, edentulous atrophic maxilla, graft volume change, implant stability

INTRODUCTION

Reconstruction of the atrophic edentulous maxilla with an autogenous bone graft and delayed endosteal implant placement is a well-established treatment modality, and predictable results are reported.[1–3] However, earlier studies using a simultaneous approach showed high implant failure rates in the range of 25 to 30%.[4,5] The most frequently used bone graft harvesting area for major reconstruction is the anterior iliac crest, where harvesting is usually associated with low morbidity[6–8] and can offer a large quantity of bone.[9] One important factor in the clinical outcome for the maxillary reconstruction is implant success or survival. With regard to implant failure pattern, single implant losses are more frequent than multiple after maxillary reconstruction.[10,11] When occurring, multiple implant failures are usually clustered in a few patients.[1,12]

For the individual patient, multiple implant failure is a severe clinical problem because the implant failures can preclude the possibilities for a fixed supraconstruction in the maxilla.

The reasons for multiple implant failures in grafted bone are important to identify. Factors that may influence the outcome could be related both to local and to

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systemic factors. For instance, the vitality and density of the bone graft itself may affect the graft incorporation process and the integration of implants. Factors related to the systemic bone metabolism probably affect the incorporation and remodeling of the bone graft in the recipient site.

Implant stability can be divided into primary and secondary stability.[13] The former is dependent on the density and quantity of the bone, the surgical technique when placing the implant, and the design of the implant. Secondary stability is achieved after healing and is dependent upon the primary stability, the bone remodeling after primary healing, and bone remodeling during loading.

In non-grafted situations, implant failure is reported to occur more often in situations with low bone density and reduced bone volume.[14] In addition, reduced implant survival has been reported for implants of shorter length (in millimeters) rather than longer ones.[13] Thus, reduced volume and density of the bone graft may increase the risk for implant failure.

It would be of interest to find prognostic factors for bone graft remodeling and implant stability for the individual patient planned for reconstruction of the atrophic edentulous maxilla. One reason for clustering of implant failures in a few patients may be related to osteopenia/osteoporosis. Osteopenia/osteoporosis can be diagnosed with bone mineral density (BMD) measurements using dual energy absorptiometry.[15] Blomqvist et al.[16] used BMD for analyzing factors of implant failure in a group of reconstructed patients with multiple implant failures and found a correlation. The structure of the bone graft can also be examined with histomorphometry in biopsies.[17,18] The mineralized bone area can be expressed in bone volume fraction (BVF) as a measurement of bone density. During the initial healing of the bone graft, three-dimensional changes appear[19,20] that can be evaluated with computer tomography (CT).[19,21,22] Hematologic factors such as markers of enzymatic activity in bone metabolism or products released during bone formation/bone resorption[23] may also serve as prognostic indicators.

The resonance frequency analysis (RFA) method is a non-invasive technique for evaluation of implant stability,[24] and the technique is sensitive enough to monitor changes of implant stability during implant healing.[25] Clinical measurements of implants during healing indicate that implants reach a similar degree of stability in spite of the degree of primary stability.[26] This pattern was also demonstrated by Sjöström et al.[3] in grafted maxillae. The authors also found a tendency toward lower resonance frequency values for implants that failed as compared with implants that remained stable. It would be of interest to see if low stability could be correlated to the properties of the bone graft, that is, density and volume changes.

The aim of this clinical study was to analyze the amount of graft volume change (GVC) during the first 6 months of bone graft healing. The purpose was also to find possible correlations between volume changes of the bone grafts during the 6 months of healing in the maxilla and factors such as BMD, BVF in biopsies, and hematologic bone metabolic factors in blood. The purpose was finally to find possible correlations between the measured factors and implant failure.

MATERIALS AND METHODS

This study included a total of 46 consecutive patients (31 women/15 men, mean age 57, range 44–73) who had their edentulous atrophic maxilla reconstructed with autogenous bone grafts and endosteal implants between 1995 and 1999. The patients were referred to the Department of Oral and Maxillofacial Surgery at Umeå University. Maxillary reconstruction was performed with an autogenous iliac bone graft and endosteal implants in a staged procedure. The patients' atrophic alveolar process in the maxilla was reconstructed with one of two techniques. For 11 patients, with a reversed maxillomandibular relation, with or without increased vertical distance, an interpositional bone graft in conjunction with a Le Fort I osteotomy was performed.[11] For 35 patients, with a thin alveolar crest or loss of bone height in the anterior maxilla, the reconstruction was carried out using a buccal onlay bone graft together with a nasal floor inlay graft.[10] Eleven patients had an additional maxillary sinus antral graft, while the remaining had a posterior onlay graft.

The harvesting of autogenous bone from the anterior iliac crest started with a skin incision following the skin lines in a posterolateral direction starting from 3–4 cm medial to the iliac crest. Using blunt and sharp dissection through the subcutaneous fat layers, the aponeurosis between the abdominal and gluteal muscles was exposed. The superior surface of the iliac crest was exposed after a sharp dissection through the periosteum following the crest. The dissection was carried out with

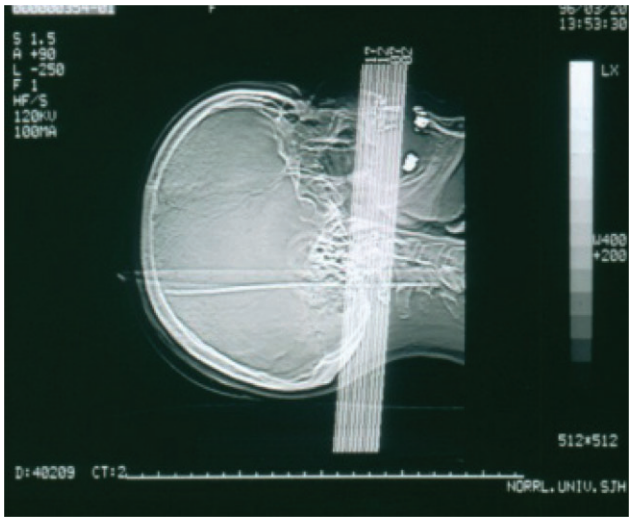

Figure 1 Radiographic examination using contiguous computer tomography.

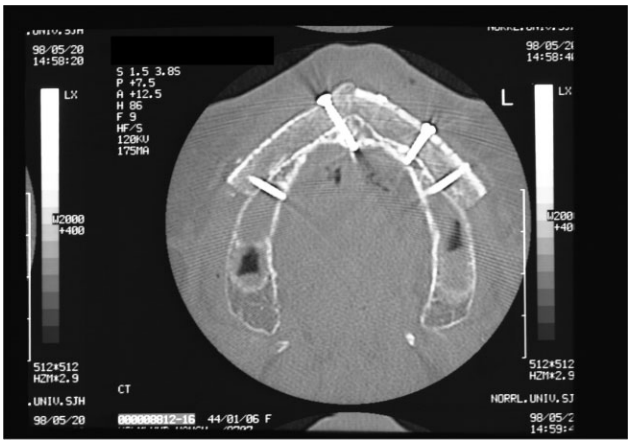

Figure 2 Axial slice post grafting.

great attention to avoid laceration of the fascia lata. Different techniques for harvesting the bone grafts in corticocancellous blocks were performed dependent upon the resorption pattern in the maxilla. The graft was outlined with a sagittal saw, and the graft was harvested with a straight osteotome. The donor site was closed in layers with special attention to the first layer – the fascia lata. This layer was sutured close to avoid marrowbone bleeding. An activated vacuum drainage was positioned between the fascia lata and the muscles until the patient was mobilized. The skin incision was closed with continuous intracutaneous resorbable sutures.

Fifteen patients (33%) were smokers at the time for bone grafting surgery. Three patients had glucocorticoid medication at the time of bone grafting surgery: two because of postoperative swelling and one patient had inhalation steroids because of asthma. Body mass index (BMI) was calculated as weight/height^2 (kg/m^2).[15] Mean BMI was 25.7 (range 19.3–38).

Radiographic examination using contiguous CT (Figure 1) (Philips Tomoscan LX Plus) was performed in 30 patients (21 women/9 men, mean age 58 years, range 44–73) for evaluation of volume changes of onlay bone grafts.

The CT was performed within 3 weeks after onlay bone grafting (Figure 2), and after 6 months of bone graft healing (Figure 3) prior to implant placement.

The distance between the axial slices was 1.5 mm and parallel to the hard palate with the first slice inferior to the alveolus/bone graft and the last slice superior to the alveolus/bone graft. The radiographic film was optically transferred into a computer. The area was calculated with help of semiautomatic software; image access analysis and a personal computer (Compaq Prolinea 4/33 s) and expressed in mm^2. The volumes of the plotted areas were calculated by adding the sums of the plotted areas and multiplying them by the thickness of the sections, $V^{tot} = \Sigma$ of plotted areas $\times$ thickness of the section[27,28] and expressed in cm^3 (Figure 4).

The procedure was performed again after 6 months of bone graft healing. The resorption was calculated as the volume of the onlay bone graft after 6 months of healing divided with the volume of the onlay bone graft directly after the grafting procedure and expressed in percent.

For the evaluation of the BVF at the donor site, biopsies were taken from the internal table of the anterior crest of the iliac bone with a 3-mm trephine bur at the same time as the bone grafting surgery was

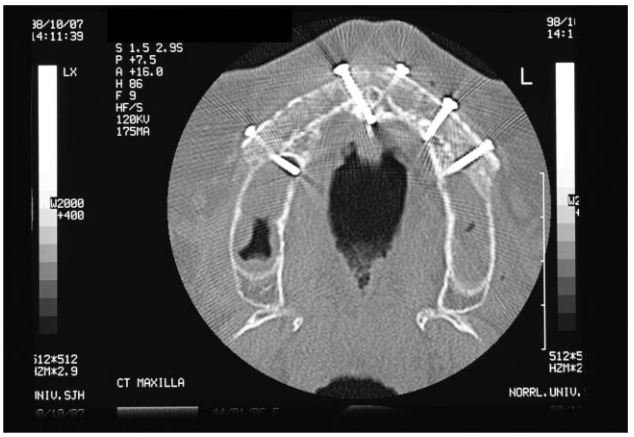

Figure 3 Axial slice representing same patient and same slice as in Figure 2, after 6 months of bone graft healing.

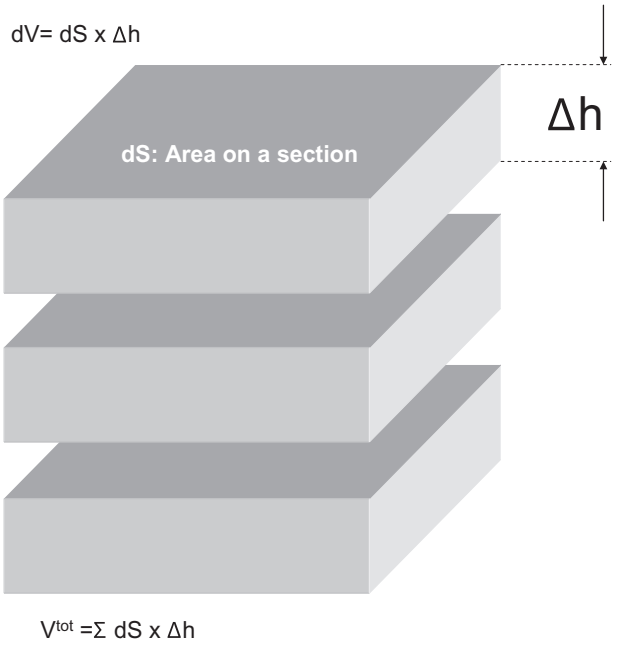

Figure 4 Diagram showing the method used for measuring the onlay bone graft volume (from Uchida et al.[27]).

TABLE 1 Hematologic Analyses from 25 Patients

Hematologic Factor	Unit
S-PTH	pmol/L
S-Albumin	g/L
S-TSH	mU/L
S-Osteocalcin	µg/L
S-Cortisol	nmol/L
S-Testosteron, total	nmol/L
S-Testosteron, free	% of total
S-Estradiol	pmol/L
S-IGFBP3 (insulin-like growth factor binding protein-3)	mg/L
S-Phosphate	mmol/L
S-IGF-1 (insulin-like growth factor)	µg/L
S-Calcitriol [1,25(OH)$_2$-cholecalciferol]	ng/L
S-ICTP (carboxy-terminal telopeptide of type I collagen)	µg/L

S-PTH = serum parathyroid hormone; S-TSH = serum thyroid-stimulating hormone.

performed in all 46 patients. The biopsy specimens were fixed by immersion in 4% buffered form solution, later dehydrated in a graded series of ethanol and finally embedded in plastic resin (Technovit® A 7210 VCL; Kulzer&Co, Hanau, Germany). According to a technique described by Donath & Breuner,[29] sections were cut and ground to a thickness of approximately 10 mm by means of Exact cutting and grinding equipment (Exact Apparatbau, Norderstedt, Germany) and stained (Figure 5).

Examination, photography, and histomorphometrical measurements were carried out using a Leitz Orthoplan microscope (Leitz, Wetzlar, Germany) (objectives 1.6× to 40×, with the ability to zoom in up to 2.5× when needed) equipped with a Leitz Microvid Morphometric System and connected to a personal computer (IBM, New York, NY). The measurements were performed at 6× and 10× magnification. The total bone area was calculated as the area of bone divided by the total biopsy area and expressed in percent.

Blood samples were collected from 25 patients (18 women/7 men, mean age 57 years, range 48–73) in conjunction with the reconstructive surgical procedure and were analyzed with regard to the factors described in Table 1.

The collected blood samples were centrifuged, and the sera were analyzed by standard methods at the Umeå University Hospital, Department of Clinical Chemistry. In a first classification based on normal ranges, the results were classified as within, over, or below normal ranges.

In 21 patients (15 women/6 men, mean age 59 years, range 50–73) the BMD (g/cm^2) was measured through

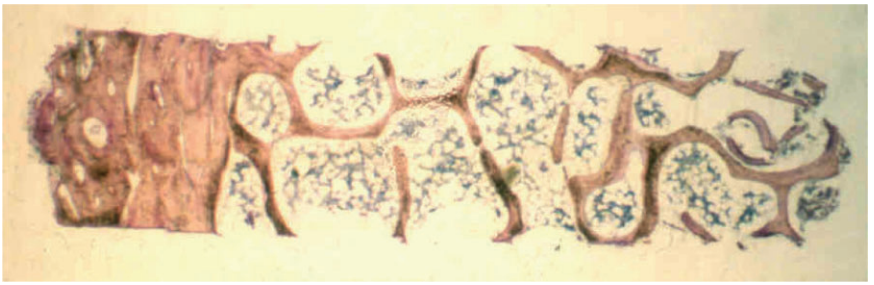

Figure 5 Biopsy from iliac crest (toluidine blue/pyronine-G + polarized light).

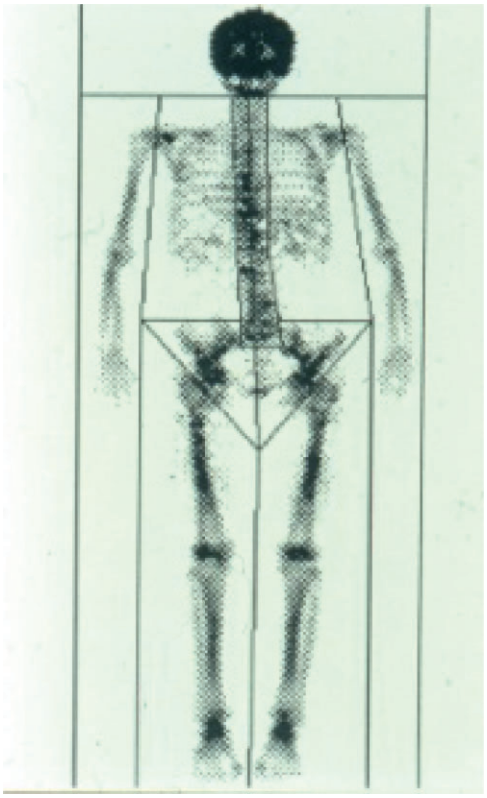

Figure 6 Bone mineral density of total body.

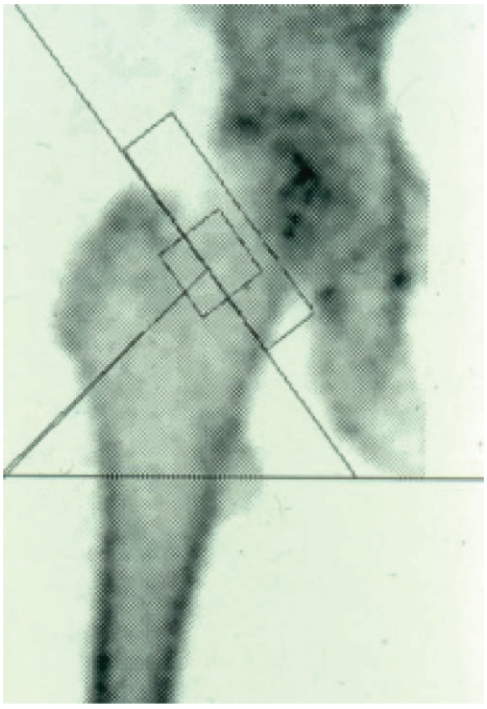

Figure 7 Bone mineral density of femoral neck.

dual energy x-ray absorptionsmetry (Lunar DPX-L, Lunar Co, Wisconsin, USA) with program version 4.6e (Voltage 76 kVp, current 150 μA, medium collimation, sample size 4.8 × 9.6, sample interval 1/32, scan width 576 mm, scan length 1958 mm). Results were obtained from whole body (whole body BMD) (Figure 6), femoral neck BMD (Figure 7) and lumbar vertebrae L2–L4 (Figure 8) and expressed as T-score.

A total of 341 Brånemark titanium implants with a turned surface (Brånemark® System, Nobel Biocare AB Göteborg, Sweden) were placed in 46 patients after 6 months of bone graft healing. Implant stability was measured at the time for implant placement with RFA in 28 patients (20 women/8 men, mean age 57 years, range 48–73). The RFA measurements were performed using an Osstell™ instrument (Integration Diagnostics AB, Göteborg, Sweden) and expressed in implant stability quotient (ISQ) units. Mean ISQ values were calculated for each patient. Implant failure, if any, was registered for each patient prior to loading and after a minimum of 3 years of loading. At the 3-year follow-up, 17 of the patients were routinely checked up without removal of the bridge. All patients were informed about the treatment and follow-up, they could withdraw from the study at any time and gave written consent to participate in the study. The principles of the declaration of Helsinki were followed.

Statistics

In univariate analysis the effects of gender, BMI, smoking, glucocorticoid medication, BVF, BMD of total body, femoral neck, vertebrae L2-L4 (expressed as T-score) on GVC were assessed by the Kruskal–Wallis test. The correlation between hematologic factors and

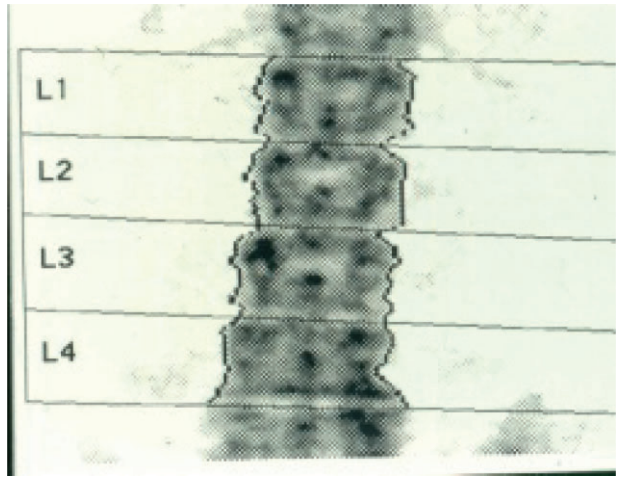

Figure 8 Bone mineral density of vertebrae L2-L4.

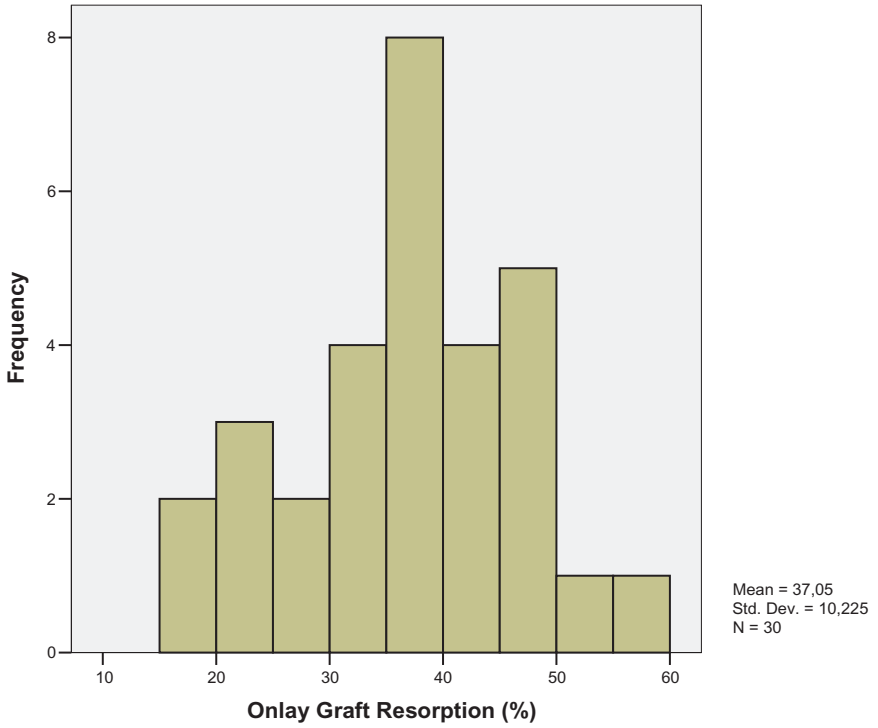

Figure 9 The resorption in percent, between bone grafting and 6 months of initial healing, for 30 patients reconstructed with onlay bone grafts.

GVC was analyzed by Pearson correlation test. The association between early and late implant failures and GVC, implant stability (expressed in ISQ), BVF, BMI, smoking, gender, glucocorticoid medication and BMD for total body, femoral neck, and L2-L4 was evaluated by unconditional logistic regression to estimate odds ratios (OR) and corresponding 95% confidence intervals (CI). The correlation between GVC and ISQ was tested with Pearson correlation test.

All p values were based on two-sided tests and considered significant if <0.05. The Statistical Package for the Social Sciences (SPSS) software package (version 13.0; SPSS Inc., Chicago IL, USA) was used for all statistical analyses.

RESULTS

The volumes of the onlay bone grafts immediately after surgery and after 6 months of healing, as measured in repeated CT radiographs, are shown in Figure 9. The average decrease in onlay bone volume after 6 months was 37% +10.2 (range 16–59).

The mean BVF in iliac crest biopsies was 32% +11.2 (range 15–74) (Figure 10).

In a first classification based on normal ranges, insulin-like growth factor binding protein-3 (serum-IGFBP3) was the only hematologic parameter that differed from the normal range with 19 out of 24 (79%) samples over the normal range.

The BMD data for 21 patients showed that 16 patients had a T-score > −1 when the total body was analyzed. BMD of femoral neck showed that eight patients had a T-score > −1 and nine patients had a T-score > −1 when vertebrae L2-L4 was analyzed.

The implant stability was evaluated with RFA in 28 patients, and the mean ISQ value at the time for implant placement was 61.5 + 9.0 (range 44.6–79.3).

In all 46 patients, rotation stability of each implant was manually tested at the abutment connection. Mobile implants were classified as failures and removed. A total of 15 patients had one or more implant failure prior to loading, classified as early failures ($n = 21$ implants). Forty-two out of 46 patients were followed a minimum of 3 years after loading of the implants. Four patients were dropouts because of: death ($n = 1$), moving out from the area ($n = 2$), or refusal to participate in the study ($n = 1$). In addition, six patients out of 42 had to have one or more implants removed during the 3-year follow-up and were classified as late failures ($n = 9$ implants).

Univariate analysis of the effect of different factors on GVC is shown in Table 2. Of all factors assessed, only

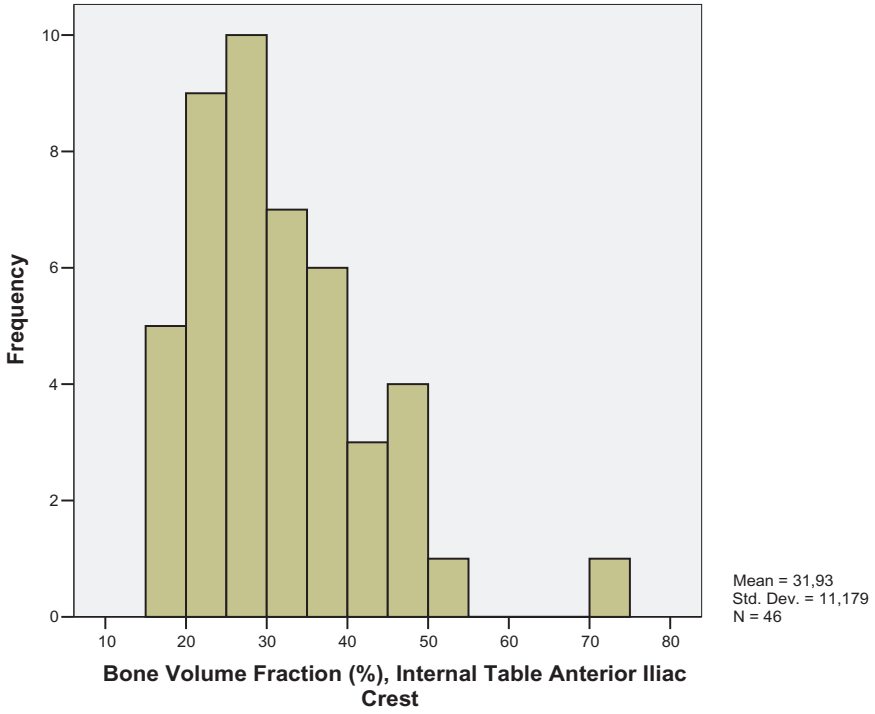

Figure 10 The bone volume fraction in 46 biopsies from internal table, crista iliaca.

BMD L2-L4 was significantly associated with GVC ($p = .017$). A non-significant correlation was found for osteocalcin and carboxy-terminal telopeptide of type I collagen (ICTP) as demonstrated in Table 2.

Tables 3 and 4 show OR with 95% CI, the association between early and late implant failures and GVC, implant stability expressed as ISQ, BVF, BMI, smoking, gender, glucocorticoid medication, and BMD for total body, femoral neck, and L2-L4 (categorized into T-score ≥−1.0 or <−1). No significant correlations were found.

No correlation was found between GVC and ISQ (Pearson correlation test, $p = .865$).

DISCUSSION

In the present study, bone grafting surgery was performed in order to reconstruct the atrophic edentulous maxilla prior to implant placement. Dimensional changes of the bone graft were evaluated by comparing CT radiographs taken immediately and 6 months after bone grafting. The mean reduction of the bone graft volume was 37%. In a comparable study by Johansson et al. 2001a,[22] a volume change of 47% was found during a similar 6-month long initial healing period. Sbordone et al. 2009,[30] found an average resorption of 42% for free iliac crest bone grafts placed as onlay bone graft in the anterior maxilla.

The difference between the results might be because of different bone harvesting techniques. The technique used in the present study aimed to obtain a large amount of cortical bone from the iliac crest.[9] This technique differs from that used by Bloomquist & Turvey[31] who recommended taking the medial, inner portion of the iliac crest to minimize surgical morbidity. Animal studies[32–34] indicate that resorption is more pronounced for cancellous bone grafts than for cortical bone grafts and that the micro-architecture (cortical vs cancellous) is more important for bone graft maintenance than the bone graft origin.[32] The importance of the architecture of the bone graft was also shown by Nyström et al.[19] who found that most of the reduction in bone graft width occurred during postoperative months 1 to 3. In contrast, the reduction in bone graft height mostly occurred between months 3 and 12 after bone grafting. They harvested the graft from *ala ilaca* via a lateral and inferior entrance in order to obtain a bicortical bone graft. Those authors concluded that the differences in resorption can probably be explained by the presence of a cortical layer on the inferior aspect on the bone graft.

Prior to bone reconstructive surgery of the present patients, 13 bone metabolic factors were analyzed. S-IGFBP3 was the only factor that differed with a majority of the samples above normal ranges. S-IGFBP3 is a

TABLE 2 Univariate Analyses of Different Factors and Their Correlation with Graft Volume Change

Factor	*p* Value
Gender	0.859†
Body mass index (categorized into two groups: <25, 25+)	0.703†
Smoking (yes/no)	0.131†
Glucocorticoid medication (yes/no)	0.948†
Bone volume fraction (categorized into two groups: <29%, ≥29%)	0.072†
Bone mineral density of total body (T-score categorized into two groups: T-score ≥−1 or <−1)	0.126†
Bone mineral density of femoral neck (T-score categorized into two groups: T-score ≥−1 or <−1)	0.852†
Bone mineral density of vertebrae L2-L4 (T-score categorized into two groups: T-score ≥−1 or <−1)	0.017*†
S-PTH (pmol/L)	0.227‡
S-Albumin (g/L)	0.584‡
S-TSH (mU/L)	0.300‡
S-Osteocalcin (µg/L)	0.061‡
S-Cortisol (nmol/L)	0.395‡
S-Testosteron, total (nmol/L)	0.770‡
S-Testosteron, free (% of total)	0.817‡
S-Estradiol (pmol/L)	0.671‡
S-IGFBP3 (Insulin-like growth factor binding protein-3) (mg/L)	0.855‡
S-Phosphate (mmol/L)	0.079‡
S-IGF-1 (Insuline-like growth factor) (µg/L)	0.292‡
S-Calcitriol [1,25(OH)$_2$-cholecalciferol] (ng/L)	0.588‡
S-ICTP (Carboxy-terminal telopeptide of type I collagen) (µg/L)	0.068‡

S-PTH = serum parathyroid hormone; S-TSH = serum thyroid-stimulating hormone.
*$p < .05$, 1: Kruskal–Wallis test, 2: Pearson correlation test.
†Kruskal–Wallis test.
‡Pearson correlation test.

binding protein for serum insulin-like growth factor-I.[35] In a study on mice,[36] an increased level of S-IGFBP3 indicated increased osteoclast number, increased bone resorption, and impaired osteoblast proliferation. This result could indicate ongoing bone resorption in the present patients. Twelve factors were within normal ranges. Parathyroid hormone, thyroid-stimulating hormone, androgen, estrogen, S-Cortisol, and S-Calcitrol are involved in the systematic regulation of bone remodeling.[37] Osteocalcin is a non-collagenous bone matrix protein synthesized by osteoblast and a sensitive marker for bone turnover and bone formation.[23] IGF-1 is involved in regulation of the osteoblast.[38] S-ICTP is released from collagen during breakdown and used as a marker for bone resorption.[39] Regulation of bone metabolism and fracture healing is a complex process,[37,40–42] and the statistical analysis could not verify a correlation between GVC and the evaluated hematologic factors. However, a non-significant correlation was found for s-osteocalcin and S-ICTP and might indicate a reduced bone remodeling.

Biopsies taken from the internal plate of the anterior iliac crest at the time of bone grafting were used for BVF analysis. The mean value for the mineralized BVF was 32%. The BVF showed a non-significant correlation to GVC. Other studies have shown that bone grafts containing more cortical bone were more resistant to resorption than grafts containing more cancellous bone.[32–34]

The BMD was measured in the lumbar vertebrae (L2-L4), in the femoral neck, and in the total body. Only BMDs of L2-L4 were significantly associated with GVCs, while BMDs of total body and femoral neck were not. This finding with different results in different parts of the body is also supported in the literature.[43] Raisz[44] wrote, "The diagnosis osteoporosis represents a continuum, in which multiple pathogenetic mechanisms converge to cause loss of bone mass and microarchitectural deterioration of skeletal structure." The results from the present study indicate that a low BMD index in L2-L4 is associated with the resorption rate in the grafted bone during initial healing. Only 21 of the patients were investigated with BMD, which limited the statistical analysis and conclusions. The patient's BMI did not affect the GVCs. The impact of weight was discussed by Kanis.[15] Individuals who weigh more have higher repetitive skeletal loads and that might decrease the bone loss.

The early phases of bone graft healing are similar to fracture healing in several respects.[45] The fracture mechanism in patients with osteoporosis is not different from that of healthy objects,[46] and the impact of osteoporosis on GVC remains unclear. In a study on changes of volume and density of calvarial split bone grafts after alveolar ridge augmentation, Smolka et al.[47] found reduced resorption rates for osteoporotic patients. However, the comparison with our study is limited because of different bone grafts. The impact of

TABLE 3 Risk of Implant Failure Prior to Loading According to Different Factors

Factor	No. of Individuals	No. (%) of Failures	OR	95% CI
GVC				
≤37.6%	15	3 (20.0%)	1.00	
>37.6%	15	7 (46.7%)	3.50	0.69–17.71
ISQ				
≤61.7%	14	6 (42.9%)	1.00	
>61.7%	14	2 (14.3%)	0.22	0.04–1.39
BVF				
≤29%	23	7 (30.4%)	1.00	
>29%	23	8 (34.8%)	1.22	0.36–4.19
BMI				
≤25	19	5 (26.3%)	1.00	
>25	27	10 (37.0%)	1.65	0.46–5.96
Smoking				
No	31	12 (38.7%)	1.00	
Yes	15	3 (20.0%)	0.40	0.09–1.70
Gender				
Male	15	4 (26.7%)	1.00	
Female	31	11 (35.5%)	1.51	0.39–5.90
Glucocorticoid medication				
No	43	14 (32.6%)	1.00	
Yes	3	1 (33.3%)	1.04	0.09–12.41
BMD total body				
≥–1.0	16	4 (25.0%)	1.00	
<–1.0	5	2 (40.0%)	2.00	0.24–16.61
BMD femoral neck				
≥–1.0	8	3 (37.5%)	1.00	
<–1.0	13	3 (23.1%)	0.50	0.07–3.44
BMD L2-L4				
≥–1.0	9	2 (22.2%)	1.00	
<–1.0	12	4 (33.3%)	1.75	0.24–12.64

BMD = bone mineral density; BMI = body mass index; BVF = bone volume fraction; CI = confidence interval; GVC = graft volume change; ISQ = implant stability quotient; OR = odds ratios.

relative bone mass density for implant survival was studied by Blomqvist et al.[16] In a retrospective analysis of 49 patients who received bone graft augmentation to the maxillary sinuses in conjunction with implant placement, 11 patients had significantly reduced implant survival rates. The group of patients with reduced implant survival had a significantly lower BMD than age- and sex-matched patients without implant failures when the bone mineral content of the forearm was measured.

In spinal fusion surgery, smoking is reported to have a negative effect on bone graft healing.[48] The mechanism behind the smoking effect is probably the inhibition of early revascularization of cancellous bone grafts.[49] Riebel et al.[50] studied in a rabbit model the influence of nicotine on the revascularization of cancellous iliac crest bone grafts and reported that nicotine decreased the vascular ingrowth. Hollinger et al.[51] wrote that nicotine in tobacco causes peripheral vasoconstriction, tissue ischemia, decreases oxygen tension, and depresses osteoblast activity. In the present study, 15 patients were current smokers at the time for the reconstruction surgery. However, smoking did not have any influence on GVC.

The negative effect of smoking on implant survival is reported by several authors.[52–54] In the reconstruction

TABLE 4 Risk of Implant Failure after Minimum Follow-Up of 3 Years According to Different Factors

Factor	No. of Individuals	No. (%) of Failures	OR	95% CI
GVC				
≤37.6%	14	5 (35.7%)	1.00	
>37.6%	14	8 (51.1%)	2.40	0.52–10.99
ISQ				
≤61.7%	13	8 (61.5%)	1.00	
>61.7%	13	3 (23.1%)	0.19	0.03–1.03
BVF				
≤29%	21	9 (42.9%)	1.00	
>29%	22	12 (54.5%)	1.60	0.48–5.34
BMI				
≤25	18	7 (38.9%)	1.00	
>25	25	14 (56.0%)	2.00	0.58–6.87
Smoking				
No	30	16 (53.3%)	1.00	
Yes	13	5 (38.5%)	0.55	0.14–2.06
Gender				
Male	15	5 (33.3%)	1.00	
Female	28	16 (57.1%)	2.67	0.72–9.87
Glucocorticoid medication				
No	40	20 (50.0%)	1.00	
Yes	3	1 (33.3%)	0.50	0.04–5.97
BMD total body				
≥−1.0	14	5 (35.7%)	1.00	
<−1.0	4	2 (50.0%)	1.80	0.19–16.98
BMD femoral neck				
≥−1.0	8	3 (37.5%)	1.00	
<−1.0	10	4 (40.0%)	1.11	0.16–7.51
BMD L2-L4				
≥−1.0	8	2 (25.0%)	1.00	
<−1.0	10	5 (50.0%)	3.00	0.40–22.71

BMD = bone mineral density; BMI = body mass index; BVF = bone volume fraction; CI = confidence interval; GVC = graft volume change; ISQ = implant stability quotient; OR = odds ratios.

situation, the smoking will probably affect both the healing and volume change of the graft and the healing of the implant in the grafted bone. Kan et al.[55] found that smoking affected the implant survival rate for implants placed in grafted maxillary sinuses. However, Sjöström et al.[56] did not find that smoking affected the implant survival in a group of patients with maxillary reconstruction.

No correlation was found in the present study between GVC and implant stability evaluated with RFA expressed in ISQ. Miyamoto et al.[57] showed that the stability, according RFA, was correlated to the cortical bone thickness and that the cortical and cancellous ratio of local bone was critical for treatment success. Östman et al.[58] found in a study on RFA measurements of implants at placement surgery in non-grafted situations that a lower ISQ was obtained for implants placed in softer bone. In the present study, the radiological examination did not analyze the amount of cortical bone in the bone graft, which limits the analysis of the density of the bone graft after the initial healing. Sjöström et al.[56] found a significant difference in primary stability between failed and successful implants.

When analyzing the risk of implant failure, prior to loading and 3 years after loading, according to the evaluated factors in the present study, no significant

correlations were found. Perhaps the material was too small or there may be other parameters that are important for implant survival.

Within the limitations of the present study, it is concluded that the volume of onlay bone grafts in the maxilla is reduced by, on average, 37% during the 6 months of healing prior to implant placement. Univariate analysis indicated that BMD of lumbar vertebrae L2-L4 expressed as T-score was significantly correlated with GVC (loss). BVF and hematologic factors did not correlate to GVC. No correlations were found between GVC and implant stability expressed in ISQ nor between implant failure and the other factors evaluated in this study.

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