The Influence of Mandibular Dentition on Implant Failures in Bone-grafted Edentulous Maxillae

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Purpose: *To evaluate the influence of mandibular dentition on the performance of maxillary implants prior to definitive prosthesis attachment in maxillae that have been reconstructed with autogenous bone grafts.* ***Materials and Methods:*** *A retrospective review of 90 consecutive patients, 31 men and 59 women, with a mean age of 57.4 years, was conducted. All patients underwent treatment planning to receive endosseous implants in the edentulous maxilla in conjunction with autogenous bone grafting. During the time from implant and/or bone graft placement until placement of the definitive restorations in the maxillae, the mandibular dentitions were recorded and categorized into 6 groups based upon the presence and distribution of teeth.* ***Results:*** *Of 643 implants placed, 118 (18.4%) were lost between implant placement and definitive prosthesis placement. The type of mandibular dentition was significantly associated with implant failure during this time interval ($P < .001$). In particular, the patients with implants opposing unilateral occlusal support showed the highest rate of implant failure (43.8%, or 28 of 64 implants). Implants that opposed a mandibular implant-supported fixed prosthesis demonstrated an implant failure rate of 14.3% (10 of 70), and in patients with a removable mandibular denture, the implant failure rate was 6.2% (4 of 65 implants failed). The overall mean patient follow-up was 64.2 months. At 60 months, the cumulative implant failure rate based on the Kaplan-Meier method was 20.2%.* ***Discussion:*** *Unfavorable concentration of forces on the maxilla may contribute to increased risk of implant failure.* ***Conclusion:*** *Effort should be made to create a favorable occlusion in the mandible, with attention being paid to broad distribution of occlusal contacts.* (Int J Oral Maxillofac Implants 2002;17:69–77)

Key words: *atrophy, autogenous bone graft, dental occlusion, dentition, endosseous dental implantation, mandible, maxilla*

Oral rehabilitation with endosseous implant–supported restorations has become an accepted treatment modality because of the high level of predictability that can be achieved using this methodology.[1–4] In some anatomic conditions, the use of implants is complicated as the result of inadequate bone volume and/or poor bone quality. This situation is encountered most frequently in the edentulous maxilla,[5–7] where anatomic limitations related to residual ridge resorption or pneumatization of the maxillary sinus create difficulties for surgical reconstruction. Augmentation procedures may use autogenous bone from a number of different donor sites. These donor sites allow the creation of sufficient bone volume for implant treatment. Several authors[8–12] have reported results of endosseous implants in onlay bone grafts harvested from the iliac crest. Critical review of these reports demonstrates variation of implant survival rates. A different surgical approach—placement of autogenous bone into the maxillary sinus—seems to be more predictable than onlay bone grafting. It is this predictability that appears to be the reason for the popularity of this treatment approach.[13–17] Unfortunately, the 2 surgical techniques are not interchangeable. Onlay bone grafts are often required when the

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maxilla is severely resorbed, since the height and width of the maxilla may need to be modified purely for prosthetic reasons.[18]

Lekholm and associates[19] reported a 3-year retrospective multicenter study of bone grafting in conjunction with implant placement that demonstrated an overall implant survival rate of approximately 80%. A literature review by Esposito and coworkers[20] reported a pooled failure rate of 15% after 3 years of loading in edentulous and partially edentulous patients. Most of the implant failures occurred during the submucosal implant healing period, at abutment connection surgery, and during the period immediately prior to connection of the definitive prosthesis.[20]

Repeated trauma to the implant and/or local bone during the healing period is considered to be a causative factor for implant failure.[21–25] This trauma could be induced by the use of a prosthesis that transmits forces to the underlying bone.[26] Kelly[27] described the phenomenon known as combination syndrome, in which the anterior maxilla undergoes residual ridge resorption in response to trauma from retained mandibular anterior teeth with a lack of stable posterior mandibular occlusion. A provisional maxillary denture opposed by a mandibular dentition that creates force concentration, rather than force distribution, could induce further trauma to the reconstructed maxilla. Force concentration is likely to occur when occlusal instability is created by factors such as the presence of unilateral edentulism or retained anterior teeth only. Conversely, an intact mandibular arch, completely restored dentition, or any other distribution of teeth that allows a broad distribution of forces should prove more favorable to the maxilla.

The aim of this study was to analyze the influence of the mandibular dentition on implant performance in the maxilla prior to definitive prosthesis attachment when reconstruction is possible only with the use of autogenous bone-grafting techniques.

MATERIALS AND METHODS

The present study was conducted as a retrospective investigation of consecutively treated patients from the Division of Oral and Maxillofacial Surgery and the Department of Dental Specialties, Mayo Clinic, Rochester, Minnesota, and the Department of Oral and Maxillofacial Surgery, Länssjukhuset, Halmstad, Sweden. A total of 101 consecutively treated patients (36 men and 65 women), all with edentulous maxillae that had not previously been treated with implants, were assessed through evaluation of the surgical records, pre- and postoperative radiographs, clinical records, and all other available diagnostic data. All patients underwent treatment planning to receive endosseous implants (Nobel Biocare AB, Göteborg, Sweden) in the edentulous maxilla in conjunction with autogenous bone grafting. The recommendation for treatment was based on the amount of bone available for implant placement. Consultations between the restorative dentist and the surgeon were used to establish the most favorable location for implants and grafts. All patients had insufficient bone volume for routine implant treatment, and autogenous bone augmentation was required. The group of patients was treated by 4 surgeons and 3 restorative dentists between January 1, 1990, and December 31, 1996.

Of a total of 101 patients, 11 subjects (10.9%) were excluded as a result of: combined infection and dehiscence of the wound because of the use of a nonresorbable membrane (n = 3 patients), maxillary discontinuity resulting from gunshot wounds or resection of malignancy (n = 2), relocation before treatment was completed (n = 3), and death (n = 3). The remaining 90 patients (31 men, 59 women; mean age of 57.4 ± 8.9 years, range 31 to 74 years) were examined retrospectively according to the study protocol (Table 1). The mean follow-up period was 64.2 months (range 22 to 105 months).

Bone augmentation was performed in a hospital operating room setting under general anesthesia with nasal endotracheal intubation. All 90 patients received autogenous corticocancellous bone blocks harvested from the iliac crest. At the recipient site, different surgical augmentation techniques were performed: segmental bone block onlay, full-arch bone block onlay (horseshoe-shaped),[11,28] or nasal bone block inlay and maxillary sinus bone block inlay[16,17,29,30] (Table 2). Both 1-stage surgery, with the bone graft and implants placed simultaneously (n = 66), and 2-stage surgery, with a healing period between bone grafting and implant placement (n = 24), were utilized (Figs 1a to 1d). Patients who received the 2-stage surgical technique had a bone graft healing period of 4 to 7 months before implant placement (Table 2). A total of 643 endosseous implants[31] were placed according to the Brånemark protocol (Table 3). All implants were commercially available at the time they were used; no experimental implants were placed in this study. Abutment connection surgery was performed after 5 to 12 months of implant healing.

The presence and distribution of the mandibular dentition during the time from implant and/or bone graft placement until placement of the definitive

Table 1 Distribution of Patients with Regard to Jawbone Shape in the Anterior and Posterior Maxilla Before Grafting Procedure*

	No. of Jaws	
Jawbone shape	Anterior	Posterior
Class I–II	0	0
Class III–IV	25	0
Class V–VI	58	90
Total	83	90

*According to Cawood and Howell.[32]

Table 2 Distribution of Patients with Regard to Different Grafting Techniques

Grafting techniques	No. of patients
Full-arch bone block onlay only	9
Segmental bone block onlay and sinus bone block inlay	36
Sinus bone block inlay only	38
Sinus bone block inlay and nasal bone block inlay	7
One-stage technique	66
Two-stage technique	24

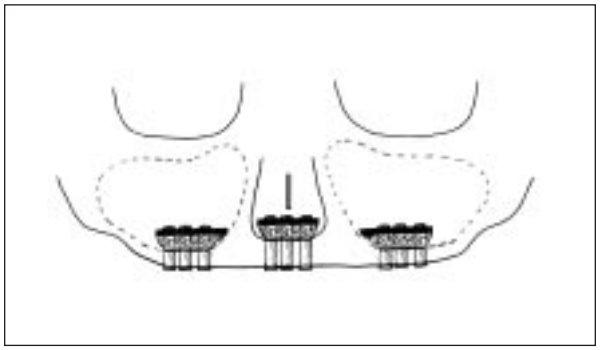

Fig 1a Sinus and nasal bone block inlay graft performed with a 1-stage technique.

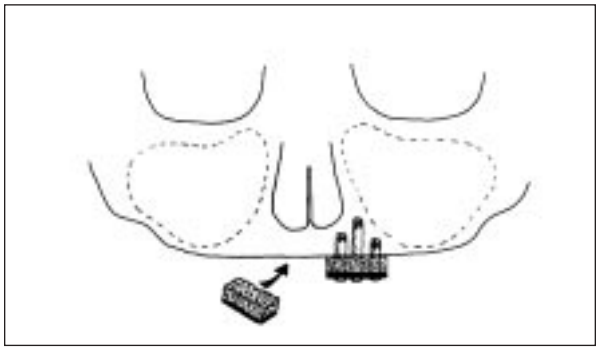

Fig 1b Segmental bone block onlay graft performed with a 1-stage technique.

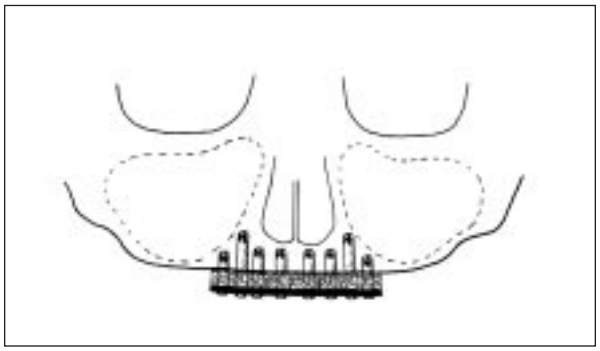

Fig 1c Full-arch bone block onlay graft performed with a 1-stage technique.

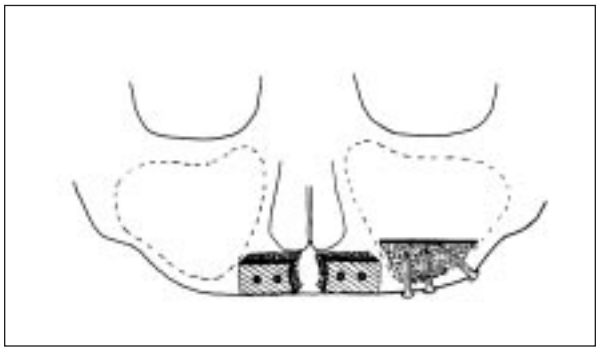

Fig 1d Segmental bone block onlay and sinus bone block inlay graft performed with a 2-stage technique.

Table 3 Distribution of Failed Implants

	Before abutment connection	At abutment connection	Before prosthesis attachment	Observation period after loading of prosthesis							
				Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
No. of implants still at risk for failure	643	625	562	523	463	387	293	194	117	24	7
No. of implants failed in interval	18	63	37	2	4	2	2	0	0	0	0
Interval failure rate (%)	2.8	10.1	6.6	0.4	0.9	0.5	0.7	0.0	0.0	0.0	0.0
Cumulative failure rate (%)	2.8	12.6	18.4	18.7	19.3	19.7	20.2	20.2	20.2	20.2	20.2

restoration was recorded, and patients were placed into 6 groups depending on this (Figs 2a to 2c). The limited occlusal support group had a mandibular dentition with a maximum of canine to canine. The unilateral occlusal support group had total occlusal support on one side and support to the first premolar at most on the contralateral side. The bilateral occlusal support group included a minimum of 1 premolar on each side. The implant-supported fixed prosthesis group had at least 2 premolars bilaterally. The last 2 groups were the removable denture group, in which the patient used a complete denture, and the no dentition group, in which the patients were edentulous but did not utilize a complete denture.

The type of provisional removable prosthesis used in the maxilla during the period between bone grafting and implant placement and connection of the permanent prosthetic construction was recorded. The utilization of provisional fixed prostheses following the implant healing period, but prior to fabrication of the definitive restoration, and the type of definitive prosthetic design were also recorded.

All available data, such as clinical records and radiographs, were documented from the time of bone augmentation or implant treatment until the last follow-up. This material was analyzed according to a study protocol to confirm understanding of the material. From patient records, the following parameters were recorded: age at the time of implant placement, gender, bone volume according to Cawood and Howell,[32] mandibular dentition, type of bone graft, number of implants placed, number and timing of implant failures, dimensions of implants, implant locations, and definitive prosthetic design.

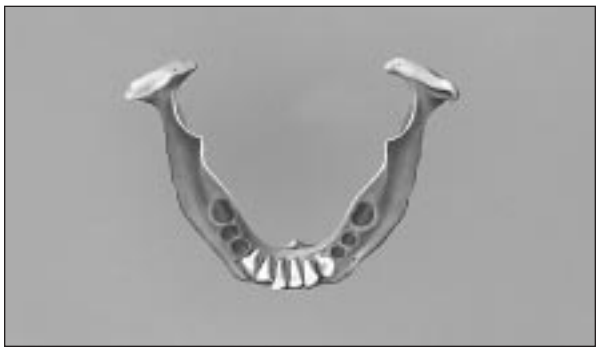

Fig 2a Limited occlusal support group.

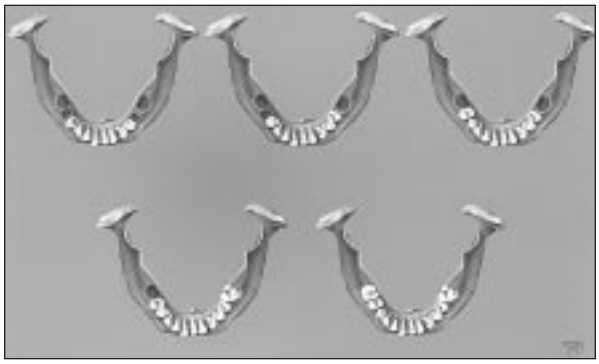

Fig 2b Types of bilateral occlusal support.

Fig 2c Types of unilateral occlusal support.

Statistical Analysis

The experimental unit in the analysis was an individual implant, of which there were several within each patient. The outcome of interest was the occurrence of implant failure at any time during the healing period, including second-stage surgery, up until the time of prosthesis attachment. Various risk factors were evaluated for their association with failure. The association between each risk factor and failure was summarized using an odds ratio (OR) and corresponding 95% confidence interval (CI). An OR indicates how much more likely implant failure is to occur in one group versus another group. An OR of 1 indicates no association between a risk factor and the occurrence of an implant failure. The binary response (failure versus no failure) was modeled using a logistic regression model. Robust estimates of the ORs and corresponding tests of significance were obtained based on generalized estimating equation methods to account for the correlation between implants within a patient. The correlations among the outcomes for each patient were modeled as exchangeable correlations. The SAS procedure PROC GENMOD (SAS Institute, Cary, NC) was used to perform the analysis.[33] All calculated *P* values were 2-sided, and *P* values less than .05 were considered statistically significant.

Table 4 Distribution of Placed and Failed Implants with Regard to Mandibular Dentition and Time of Failure

		Failed implants		
Mandibular dentition	**Total placed (failed) (%)**	**Before abutment connection**	**At abutment connection**	**Between abutment connection and prosthesis attachment**
No mandibular dentition	8 (0) (0%)	0	0	0
Removable denture	65 (4) (6.2%)	0	3	1
Limited occlusal support	70 (14) (20.0%)	1	8	5
Unilateral occlusal support	64 (28) (43.8%)	7	12	9
Bilateral occlusal support	366 (62) (16.9%)	6	35	21
Implant fixed prosthesis support	70 (10) (14.3%)	4	5	1
Total	643 (118) (18.4%)	18	63	37

RESULTS

Of the 643 consecutively placed implants in 90 patients, 81 implants (12.6%) were lost during the period from implant placement until and including abutment connection surgery. Ten patients lost 4 or more implants before prosthetic loading, and 5 of these patients lost all their implants. At the time of definitive prosthesis placement, an additional 37 implants were lost, resulting in a total of 118 lost implants (18.4%). During the first year of functional loading with the definitive prosthesis, an additional 2 implants failed to maintain osseointegration, and 8 implants were lost subsequent to that time. The overall mean patient follow-up was 64.2 months. At 60 months, the cumulative implant failure rate based on the Kaplan-Meier method was 20.2% (Table 3). All bone grafts were stable.

The type of mandibular dentition was significantly associated with implant failure during the period from implant placement until the time of definitive prosthesis placement ($P < .001$; Table 4). Implants placed opposing unilateral occlusal support were 3.6 (95% CI, 1.3 to 9.7), 4.6 (1.1 to 19.2), and 12.3 (3.1 to 48.1) times more likely to fail in this interval than implants placed opposing either bilateral occlusal support, an implant-supported fixed prosthesis, or a removable denture, respectively. In addition, implants placed opposing either bilateral occlusal support or limited occlusal support were 3.4 (95% CI, 1.1 to 10.5) and 4.1 (1.1 to 15.4) times more likely to fail, respectively, than implants placed opposing a removable denture. In the unilateral occlusal support group, 28 of 64 implants were lost, indicating the highest rate of implant failure (43.8%). Among the implants placed opposing limited occlusal support, 14 of 70 were lost (20.0%). Patients with stable occlusal contact, defined as mandibular bilateral occlusal support or an implant-supported fixed prosthesis, demonstrated implant failure rates of 16.9% (62 of 366) and 14.3% (10 of 70), respectively. The lowest implant failure rate was observed in the patients who wore a mandibular removable denture, with a failure rate of 6.2% (4 of 65 implants failed). No failures were observed in the no dentition group, which consisted of 1 patient with 8 implants (the small sample size limited any statistical comparisons).

The implant failure rate was analyzed in relation to the type of bone graft and implant location (Table 5). Implants placed in segmental bone block onlay graft were 2.5 (95% CI, 1.2 to 5.5) and 14.4 (95% CI, 3.7 to 56.5) times more likely to fail than implants placed in nongrafted bone or placed using a full-arch bone block onlay graft, respectively. Implants placed using a full-arch bone block onlay graft were significantly less likely to fail compared to each of the other types of bone grafts. Implants placed in segmental bone block onlay graft incurred a higher failure rate (32.5%, or 26 of 80 implants), compared with the implants placed in nasal or maxillary sinus bone block inlay graft, which had failure rates of 16.7% (4 of 24 implants) and 20.4% (67 of 329 implants), respectively. Implants placed in nongrafted bone revealed a failure rate of 13.1% (19 of 145 implants). The group of 9 patients who received a segmental bone block

Table 5 Distribution of Placed and Failed Implants with Regard to Type of Bone Augmentation Technique and Tooth Region

		Location (failed implants)			
Graft type	Total placed (failed) (%)	Incisor region	Canine region	Premolar region	Molar region
Full-arch bone block onlay	65 (2) (3.1%)	20 (0)	18 (0)	24 (1)	3 (1)
Segmental bone block onlay	80 (26) (32.5%)	59 (21)	20 (5)	1 (0)	0 (0)
Nasal bone block inlay	24 (4) (16.7%)	18 (2)	6 (2)	0 (0)	0 (0)
Sinus bone block inlay	329 (67) (20.4%)	1 (0)	42 (11)	193 (34)	93 (22)
Nongrafted bone	145 (19) (13.1%)	65 (10)	63 (8)	16 (1)	1 (0)
Total	643 (118) (18.4%)	163 (33) (20.3%)	149 (26) (17.5%)	234 (36) (15.4%)	97 (23) (23.7%)

Table 6 Distribution of Placed and Failed Implants with Regard to Length and Diameter

		Length (mm)						
Diameter (mm)	Total placed (failed) (%)	7	8	10	13	15	18	20
3.75	574 (100) (17.4%)	1 (1)	—	55 (13)	184 (46)	233 (31)	96 (8)	5 (1)
4.0	64 (17) (26.6%)	10 (2)	—	32 (9)	14 (2)	3 (1)	5 (3)	—
5.0	5 (1) (20.0%)	—	1 (1)	4 (0)	—	—	—	—
Total	643 (118) (18.4%)	11 (3) (27.3%)	1 (1) (100%)	91 (22) (24.2%)	198 (48) (24.2%)	236 (32) (13.6%)	101 (11) (10.9%)	5 (1) (20.0%)

onlay graft experienced a failure rate of 3.1% (2 of 65 implants). Implants placed in the premolar or molar region were typically placed in maxillary sinus inlay grafts. Implants placed in sinus inlay grafts in the molar region were 2.1 times more likely to fail than implants placed in the premolar region (23.7% [22 of 93 implants] versus 17.6% [34 of 193 implants], respectively).

Distribution of implant failures relative to implant length and diameter is shown in Table 6. The majority of the implants were 3.75 mm in diameter (89.2%). The implant failure rate tended to improve with increasing implant length, with failure rates of 33.3% (4 of 12) for 7- and 8-mm implants, 24.2% (70 of 289) for 10- and 13-mm implants, and 12.9% (44 of 342) for 15-, 18-, and 20-mm implants. Implants that were 10 or 13 mm in length were 1.9 times (95% CI, 1.1 to 3.1) more likely to fail than implants that were 15, 18, or 20 mm in length. There were too few implants that were 7- or 8-mm long to make statistical comparisons.

Provisional dentures for the reconstructed maxilla were routinely provided for all 90 patients during the healing period. Provisional prosthesis fabrication was initiated as soon as 1 to 3 weeks after bone grafting and/or implant placement. Of the 90 patients, 74 used a provisional prosthesis during the time between abutment connection surgery and the time of placement of the definitive prosthesis. The remaining 16 patients received provisional fixed prostheses immediately after abutment connection surgery. A mean of 5.7 weeks (range, 1 to 33 weeks) after the abutment connection surgery, 68 patients were reconstructed with fixed prostheses and 4 received overdenture prostheses; the 4 patients who experienced failure of all implants were treated with a conventional complete maxillary denture. Subsequent to implant failure, 14 patients were treated with additional implant placement surgery, 12 obtained fixed prostheses, 1 received an overdenture prosthesis, and 1 received a complete denture.

The follow-up period ranged from 22 to 105 months, with a mean of 64.2 months (5 years and 4 months). The time of postoperative radiographic assessments varied. Marginal bone loss was not

evaluated in this study because of the inconsistent frequency of radiographs. A preoperative classification according to Cawood and Howell[32] was accomplished retrospectively with the help of panoramic and lateral radiographs, but this was not correlated with postoperative data.

DISCUSSION

The type of mandibular dentition, occlusion, and bite force might be of significance to early implant failures in bone-grafted edentulous maxillae. Another factor for early implant failure in bone-grafted patients might be the poor bone-to-implant interface, which seems to be more sensitive to mild trauma. It is thought that trauma interferes with early integration, a situation that is exacerbated when there is a limited volume of bone at the interface of the implant and the host bone.[25]

A report of an autopsy specimen of 6 stable Brånemark System implants (Nobel Biocare) obtained from a bone-grafted patient who died 4 months after implant surgery revealed minimal bone in direct contact with the implants.[34] A similar histologic finding was observed in graft material by Esposito and coworkers,[25] in which implants were found not to be integrated at the time of abutment connection. A heterogeneous interface, with areas of highly vascularized connective tissue and portions of bone, was described. Where bone was present, there was always evidence of bone detachment from the implant surface by erythrocytes resulting from bleeding. This could indicate that manipulation of the implants at abutment surgery and during the restorative treatment phase might cause bleeding from mechanical disruption of the bone-implant interface.[35] "Reosseointegration" of implants with rotation mobility may be possible if the implants remain unloaded for a longer healing period,[35,36] but this situation is likely subject to further atraumatic healing.

Occlusal loading during the healing period could result in inadequate tissue healing and thereby impair osseointegration.[37] Jensen and associates reported a grafting technique similar to that used in this study, with an implant survival rate of 88% after at least 6 months of loading.[38] It was noted that special care was taken to minimize occlusal trauma to the maxilla during the healing period. The patients were instructed not to use their maxillary prostheses during the entire healing period of 6 months.

It may be prudent to place the implant deeper within the graft in an effort to avoid trauma to the implant from the provisional prosthesis, but this will create reduced cortical bone–implant contact, with less favorable primary stability. It is possible that the use of an internal space screw during the healing period, rather than the conventional cover screw, might minimize the risk of trauma to the implant.

It has been suggested[39–41] that fixed prostheses create more favorable force distribution to dental implants compared to removable prostheses. Applying this hypothesis to the edentulous maxilla, it may be prudent to consider fixed immediate loading of transitional implants in the labile bone of an autogenous graft, rather than allowing force transmission through a provisional prosthesis that depends on soft tissue of the residual ridge and hard palate for prosthesis retention, support, and stability. Further studies will be necessary before this concept can be used clinically on a routine basis.

A correlation between bite force and implant failure during the healing period has not been described in the literature. However, what is known is that bite force with implant-supported prostheses is greater than that with removable dentures. Carr and Laney[42] reported a significant improvement in biting force when patients changed from conventional tissue-supported prostheses to implant-supported prostheses in the mandibular arch. The mean maximal force was 59.6 N in the case of conventional removable dentures and 112.9 N for the patients who had received a mandibular implant-supported fixed prosthesis. These findings, together with the results of the current study, suggest that an unfavorable concentration and/or magnitude of force could threaten the healing implants. Future studies addressing these issues may help to determine whether there is an association between bite force and implant failures.

According to the findings of this report and the latter-mentioned reports, it seems reasonable to suggest that one causative factor for early implant failure might be the traumatic influence from the opposing arch during the healing period of bone grafts and implants. The trauma caused by a provisional maxillary denture opposed by a mandibular dentition that creates force concentration rather than force distribution could induce further trauma to the maxilla. The results of this study showed an association between a unilateral mandibular dentition and an increase in implant failure in the maxilla. This correlation has not been described before, but the influence of the mandibular dentition on maxillary complete removable dentures is well known.[26]

Given the observation that implant failure occurs at a higher rate when the opposing occlusion is not well distributed, it might be appropriate to suggest

that patients who have undergone a bone grafting procedure and implant treatment in the maxilla should not wear a provisional prosthesis during the healing period, if the mandibular dentition demonstrates a limited or unilateral occlusion. Another suggestion is to restore the mandible to a situation of bilateral occlusion prior to bone grafting and implant treatment in the edentulous maxilla. This would ensure a broad distribution of teeth and stable occlusion, which should distribute forces more favorably to the maxilla and thereby encourage implant survival. However, it is impossible to attribute failure rates to the effect of mandibular dentition alone, as more uncontrolled and unknown parameters may very well play an additional role in implant failure.

CONCLUSION

Autogenous bone grafting with implant placement carries a higher risk of implant failure than implant placement without grafting procedures. An unfavorable concentration of forces on the maxilla may contribute to an increased risk of implant failure. If grafting is required in the edentulous maxilla, every effort should be made to create a favorable occlusion in the mandible, with attention being paid to broad distribution of occlusal contacts.

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