Bone Defect Formation During Implant Placement Following Alveolar Distraction

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Purpose: *This retrospective study was designed to evaluate the volume of hard tissue generated at the time of implant placement in distracted alveolar bone.* ***Materials and Methods:*** *All patients who underwent distraction osteogenesis between 2000 and 2003 were included. The preoperative bone height, amount of distraction performed, and presence or absence of complications affecting implant placement were recorded. The augmentation achieved was correlated with insufficient bone formation using the Spearman correlation and the Fisher exact test.* ***Results:*** *The study included 43 implants placed in 17 cases of alveolar distraction. Of the 34 implants placed in bone augmented by 4.5 to 6.5 mm, bone defects were observed with 12. All 9 implants placed in ridges augmented by 7 to 10.5 mm demonstrated a bone defect. The "defect" and "no-defect" implant groups differed significantly with respect to preoperative bone height and amount of distraction performed (*$P < .001$ *for both). Significantly more defects were formed in bone augmented by > 25% compared to bone augmented by ≤ 25% (*$P < .001$*).* ***Conclusions:*** *When considering distraction osteogenesis, augmentation of up to 25% of the initial bone height seems more predictable and less likely to be associated with complications at the time of implant placement. In distractions greater than 25% of the original height, additional treatment should be considered.* Int J Oral Maxillofac Implants 2007;22:47–52

Key words: *alveolar distraction, bone regeneration, dental implants, distraction osteogenesis*

Distraction osteogenesis (DO) is a tissue engineering method applied in the reconstruction of vertical alveolar ridge deficiencies that results in both hard and soft tissue formation. Complications may occur during surgery, the augmentation period, or consolidation of the distracted bone.[1] Implant placement in distracted alveolar bone could result in bone defect formation[2,3] and occasionally in insufficiently attached gingiva.[4,5] Implant fenestrations and dehiscences can be treated using guided bone regeneration (GBR) with demineralized freeze-dried bone and expanded polytetrafluoroethylene (e-PTFE) membranes[6] or bovine bone and collagen membranes,[3] while insufficiently attached gingiva can be treated by vestibuloplasty.[4]

Discontinuity in buccal cortical bone after the consolidation period following alveolar DO is relatively more frequent, as demonstrated by both experimental[7,8] and clinical studies.[3,5,9–11] The narrowing of the distraction gap is attributable to soft tissue pressure during the alveolar distraction process in the canine mandible.[7]

Despite successful long-term results in the distraction of long bones,[12,13] Aronson[14] noticed poor bone formation in approximately 10% of cases undergoing distraction. Supplemental bone grafting was necessary in cases where fibrous nonunion or cystic forma-

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tion had occurred.[15,16] To treat severe alveolar bone defects, Block and Baughman[17] suggested that secondary bone grafting be considered in the early stages of treatment planning. It is probable that bone defect formation with alveolar DO occurs more often than it is reported in articles[2,6,11] or meetings.[18] In their first case series, Klug and associates[10] found semilunar excavation of the entire bone surface of the regenerate. One preliminary classification described 4 morphologic categories of regeneration in the distraction gap following alveolar distraction osteogenesis, from sufficient bone formation to the complete absence of bone.[3]

Gaggl and associates[4] placed 62 distraction implants with good success (an average distraction gain of about 5 mm); in 1 case an unstable distraction implant was replaced with a conventional one, and the bone was augmented using GBR. However, secondary bone grafting after implant placement was necessary for more than half of patients in another study with an average distraction of 6.5 mm[5] and for all patients in a third study where the amount of bone distracted was greater than 10 mm.[17]

The aim of this study was to evaluate the occurrence of insufficient tissue formation following implant placement as related to the length of distraction and the original bone height.

MATERIALS AND METHODS

This retrospective study included all patients consecutively treated between 2000 and 2003 at the Oral Surgery Unit, Faculty of Medicine, University of Santiago de Compostela, Spain. The patients demonstrated partially or completely edentulous alveolar ridges with a variety of resorption levels and antagonist tooth presence. Because of reduced stability and insufficient prosthesis retention, the viability of the implant placement was analyzed. Preoperative bone height was evaluated with a computerized tomographic (CT) scan (Dentascan; Siemens, Erlangen, Germany), using barium-coated stents for determination of optimal implant sites. The available bone height for each implant planned was measured from the alveolar crest and inferior margin in the mandible or from the floor of the nasal cavity or maxillary sinus in the maxilla. All patients included in the study chose treatment involving a fixed prosthesis and signed the written consent form.

In all cases alveolar distraction was performed with the Lead System (Stryker/Leibinger, Kalamazoo, MI). Surgical treatment was performed following the procedure of Chin,[19] as previously described.[20,21] Postoperatively, patients received amoxicillin (500 mg/8 h for 7 days), ibuprofen (600 mg/8 h for 4 days), and chlorhexidine 0.12% (twice a day for 2 weeks). Distraction was performed in all patients following the same protocol, with a latency period of 7 days and distraction rate of 0.5 mm/12 h. The amount of distraction performed varied depending on the individual. The distractors were removed after 3 months of consolidation of the distracted bone, and the implants were placed.

All complications during treatment were recorded. The formation of hard tissue was evaluated at the time of implant placement. In the case of bone defect formation, the treatment of choice was augmentation with bovine bone (Bio-Oss; Geistlich Pharma, Wolhusen, Switzerland) and a collagen membrane (Bio-Gide, Geistlich Pharma).

The statistical analysis was performed using SPSS for Windows (Release 11.0, standard version; SPSS, Chicago, IL). Comparisons were made using independent Student *t* tests to ascertain differences in bone height and distraction performed for implants placed in alveolar ridges with and without bone defect formation. The correlation between amount of augmentation performed and the occurrence of bone defect formation was formulated using the Spearman correlation and the Fisher exact test. $P < .05$ was considered significant.

RESULTS

Seventeen DO procedures (15 mandibular and 2 maxillary) were performed in 12 patients (7 women and 5 men; age range, 23 to 58 years; mean age, 46.5 years). A total of 43 implants, 33 Straumann (Straumann, Basel, Switzerland) and 10 Frialoc (Friadent, Mannheim, Germany) were placed in distracted alveolar bone, 38 in the mandible and 5 in the maxilla. In all cases alveolar DO permitted the placement of implants with sufficient primary stability.

Twenty-two of 43 implants were placed without the formation of bone defects, whereas 8 implants demonstrated bone fenestrations and 13 demonstrated bone dehiscences. In 6 alveolar ridges (5 mandibular and 1 maxillary), no bone defect formation occurred during implant placement; 16 implants were placed in these ridges. In 7 ridges (6 mandibular and 1 maxillary), all implants placed demonstrated bone defect formation. In the remaining 4 mandibular alveolar ridges, 5 implants were placed with bone defect formation and 6 were placed without bone defect formation.

The amount of augmentation performed for all 22 implants placed without bone defect formation was between 4.5 and 6.5 mm. Of 21 implants placed for

which bone defect formation was observed, 12 implants were placed in alveolar bone distracted between 4.5 and 6.5 mm; of these, 8 were associated with fenestration and 4 with dehiscences. All 9 implants placed in bone distracted between 7 and 10.5 mm were associated with the formation of a bone dehiscence.

The mean preoperative bone heights for implants placed with and without bone defect formation were 17.52 ± 5.95 mm and 21.95 ± 2.98 mm, respectively. The mean of amounts of distraction performed for the 2 groups of implants were 6.99 ± 2.03 mm and 5.13 ± 1.05 mm, respectively. The "defect" and "no-defect" groups differed significantly with respect to both preoperative bone height ($P < .001$) and amount of distraction performed ($P < .001$).

The mean percentages of augmentation performed (from the inferior border of the mandible to the alveolar ridge in the mandible or from the floor of the maxillary sinus/nasal fossa to the alveolar ridge in the maxilla) were 23.30% ± 4.18% for the no-defect group and 36.61% ± 8.59% for the defect group (Fig 1). The correlation between the occurrence of bone defect formation and the percentage of augmentation performed was statistically significant (Spearman's correlation; $P < .001$).

Seven of 8 alveolar ridges augmented up to 25% and 1 of 9 alveolar ridges augmented more than 25% of the original ridge height demonstrated sufficient bone formation. In the ridge where bone defect formation occurred despite the relatively small amount of augmentation (≤ 25%), only 1 of 2 implants placed was associated with defect formation. Thus, all but 1 of the implants placed in alveolar bone distracted up to 25% were in the no-defect group.

The 20 other implants associated with bone defect formation were all placed in alveolar bone distracted more than 25% from the original height. The difference between the occurrence of bone defect formation in cases where distraction increased the amount of bone by more than 25% and cases where bone was increased by up to 25% was statistically significant (Fisher exact test; $P < .001$).

Other complications occurred during distraction, and occasionally these influenced the extent and localization of bone defect formation. In 1 case, although there was no bone defect formation, lingual inclination of the transport segment was observed during distraction. Within the defect group there was 1 case of lingual inclination of the distraction vector in an implant associated with a fenestration, and among implants associated with bone dehiscences, 2 cases of fracture of the transport segment and 1 case of vector inclination occurred.

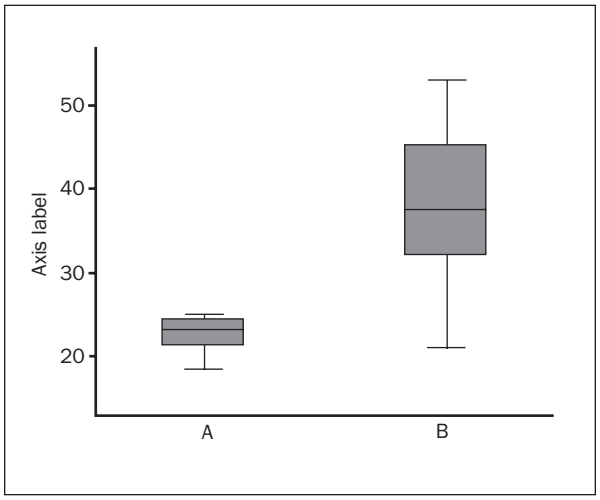

Fig 1 Box-whisker plots demonstrating the percentage by which the alveolar ridge was increased in *(a)* the no-defect group and *(b)* the defect group. Each plot shows the median, quartiles, and range (excluding outliers).

DISCUSSION

Although good results can be achieved with alveolar DO, tissue reconstruction remains difficult, and the results are often imperfect. In addition to DO, the formation of new tissue by vestibuloplasty is sometimes necessary to reconstruct insufficient attached gingiva and buccal cavities.[4,5,22–25] Moreover, fenestrations and dehiscences at implant placement can jeopardize and prolong the overall treatment period. Reduced bone volume in the facial regenerate zone has been found in both clinical studies[2,3,5] and experimental studies.[7,8,26] Block and associates[27] have documented that both buccal and lingual cortical bone are thinner in distracted bone than in nondistracted alveolar cortical bone. The results of the present study demonstrated an increased tendency for bone defect formation during implant placement in ridges as the amount of distraction performed increased. Of course, the amount of distraction required was increased in cases with decreased preoperative bone height.

Longer lengthening tends to produce an hourglass appearance in the lengthened segment.[15,28] As established by Ilizarov,[12] the level of osteogenic activity within the distraction zone depends on the amount of damage to the bone marrow, periosteum, and nutrient vessels occurring at the time of osteotomy; the rate of distraction; and the degree of stability. There is no reason to believe that these critical parameters do not play an equally important role in distraction of the craniofacial bones.[29] Among possible causes that could contribute to bone defect formation are cortical bone loss related to the

absence of teeth and the need for appropriate positioning of the implants.[6] It seems that the quantity and quality of distracted alveolar bone in the jaws did not differ in terms of occurrence of bone defect formation, although this was not statistically tested in the present study. Horizontally deficient distraction sites found as a consequence of local anatomic conditions could not be augmented by vertical distraction, and thus such deficiency should not be considered a complication of vertical DO.

Disruption of the buccal mucoperiosteum would result in the vascular embarrassment of the underlying alveolar bone[26] and granulation tissue invasion into the distraction gap, which may account for semilunar excavation of the entire bone surface of the regenerate.[3,10,11] The periosteum is probably the most important structure for successful regeneration of bones.[30,31] In cases where DO failed, Aronson[14] consistently found that the lack of local blood supply inhibited the process.

A latency period of 7 days diminishes migration of connective tissue in the region of the gap.[19] Such a delay permits the establishment of a resilient extraosseous blood supply.[32] One study found that the use of the latency period in craniofacial DO did not have a statistically significant influence on the occurrence of fibrous nonunion.[33] In the present study, despite the use of a recommended latency period, approximately one fourth of the implants placed in alveolar bone distracted from 4.5 to 6.5 mm were associated with bone fenestration on the wound side. Distraction could still occur with a latency period of up to 21 days.[34] It is possible that in human patients a longer period might enhance the osteogenic response.

The rate of bone regeneration within the distraction gap during limb lengthening is sometimes inadequate; in cases of delayed bone formation, secondary bone grafting may be required.[16,35] Ideally, the bone formation rate equals the distraction rate.[28,35] Local mechanical signals determined by the boundaries of the physiologic window affect the rate of bone remodeling.[34]

Gaggl and associates[4] reported the need for additional grafting in 1 of 62 distraction implants, with an average vertical gain from distraction of about 5 mm. In alveolar distractions greater than 5 mm, Jensen and associates[5] observed patches of radiolucency without clinical consequence 1 year after osteotomy, most often in cases where both vertical and horizontal movement was carried out. All cases in the study of Block and Baughman[17] that had greater than 6 mm of hard and soft tissue loss required bone grafting after distraction. Following the protocol used in the present study, bone defect formation might be expected in all ridges augmented by 7 to 10.5 mm and in approximately a third of implants placed in ridges augmented by up to 6.5 mm. The incidence of bone defect formation appeared to be considerably lower in ridges augmented by up to 25% of initial bone height than in those augmented by more than 25% of initial bone height.

After 20% lengthening of the lower limbs of rabbits, Li and associates[36] noticed that the rate and rhythm of distraction could slightly exceed the growth capacity of the associated capillaries. In the present study, the rate of 0.5 mm/12 h was demonstrated to be unfavorable in cases where the bone height was increased by more than 25%. Ilizarov[13] demonstrated in long bones that the distraction rate of 1 mm every 24 hours could damage arterioles of the paraosseous tissues. Meyer and associates[37] found that the assembly of collagen bundles depends on the magnitude of the strain and not the frequency of the peak strains applied. Moreover, the number of times per day distraction is carried out (once, twice, or 4 times daily) does not appear to affect the rate of fibrous nonunion in craniofacial DO.[33] Thus, a rate slower than 1 mm/24 h might be less disruptive and decrease the connective tissue invasion in the region of gap in cases of where the distracted tissue is greater than 25% of the original height.

One possible explanation for implant fenestration occurrence in cases with the distractions less than 6.5 mm could be the excessive length of the threaded rod. A prominent threaded rod during the consolidation period could result in a longer arm with a greater torque, which could cause instability of the transport segment and compromise the recipient site.[38,39] Meyer and associates[37] emphasized the necessity of avoiding undesirable peak micromotion during bone regeneration. To avoid this problem, distractor placement can be planned on articulator-mounted casts.[1] It may be advisable to shorten the threaded rod following the distraction period. Moreover, the use of a rigid instead of a semirigid distractor might produce minor fenestration.

Bone dehiscence defects as a result of vector deviation during distraction can be the result of fracture of the transport segment at the time of surgery or traction from the palatal or lingual mucoperiosteum or the muscles of the floor of the mouth. It is possible that semirigid distractors do not have sufficient stability to resist soft tissue traction following distraction during the consolidation period. To prevent possible vector deviation, one option would be to insert the threaded rod deeper in the basal bone. Relapse should be also considered as a possible reason for decreased bone height. Thus, the application of 20%

overcorrection might be of benefit.[40] In the present study, obvious vector deviation occurred in only 2 cases of implant dehiscence.

Whether a consolidation period of 3 months is optimal for distraction greater than 25% of the original height is questionable. Leaving the apparatus on longer than necessary can be as harmful[15] as removing the fixator too early.[38] However, human distraction gaps do not necessarily heal by 8 weeks.[26] The effect of implant loading on the distracted callus should also be considered.

Considering results of the present study, an additional treatment modality should be considered in cases where the planned distraction is more than 25% of the initial ridge height. The amount of limb lengthening with an acceptable complication rate should not exceed 25% of the initial bone length.[41] The healing process in the region of the distraction gap is a very complex process affected by the different regeneration patterns of the tissues. One option to prevent connective tissue invasion in the gap region would be the placement of a titanium membrane over the buccal cortex, but because of its rigidity the membrane could create pressure, resulting in mucosal dehiscence. Mofid and associates[42] demonstrated that mandibles submitted to a modified protocol of alternated distraction and compression, called "callus massage" or "callus pumping," showed more mature bone with a greater remodeling rate and increased cortical thickness compared to mandibles submitted to distraction. In addition, compression may impede the invasion of soft tissue in the distraction gap. However, it is not possible to perform "callus massage" with all types of distractors. The addition of growth factors in more difficult cases should be also considered.[43] Further experimental and clinical research is need to find methods of preventing bone defect formation and achieving more predictable results with alveolar DO.

CONCLUSIONS

Considering the results of the present study, insufficient bone formation during implant placement following alveolar distraction osteogenesis might be a relatively frequent complication. The present results confirm that bone regeneration during alveolar DO is influenced by the magnitude of the distraction gap. Following the protocol performed, the formation of bone defects at the time of implant placement was mainly related to the percentage of augmentation applied considering the initial bone height. Bone formation in the distraction gap seems more predictable in cases where the bone height is increased by up to 25%. An additional treatment modality should be considered in cases where it is necessary to increase the initial bone height by more than 25%.

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