Long-Term Block Graft Stability in Thin Periodontal Biotype Patients: A Clinical and Tomographic Study

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Purpose: *To assess the esthetic and functional outcome, as well as the volume maintenance, of autogenous block grafts placed in anterior sextants of thin periodontal biotype subjects over a long-term period.* ***Materials and Methods:*** *Fifteen consecutive patients were followed up yearly for an average of 40 months after autogenous block grafting. Preoperative and postoperative cone beam computed tomographic scans were analyzed to evaluate bone volume maintenance around the implants placed in the grafted sites. Clinical parameters (mucosal recession and implant transparency through the soft tissue) were assessed at prosthesis delivery and follow-up to evaluate the esthetic outcome. Digital photographs were used to confirm clinical outcomes.* ***Results:*** *The average augmentation per site was 2.2 times the initial buccolingual (BL) width, and 97% of the augmented width was maintained after 3.3 years. The difference between preaugmentation and postaugmentation BL width, 3.3 versus 7.4 mm, was statistically significant (*$P < .0001$*; CI 95%: 3.4 to 4.9 mm). There was a lack of implant transparency or mucosal recession around the implants in all 15 patients after an average of 40 months.* ***Conclusions:*** *Autogenous block grafting seems to be a predictable treatment modality to reconstruct alveolar ridge defects in the long term. A thin periodontal biotype did not seem to affect the volume of transplanted bone for the population studied.* Int J Oral Maxillofac Implants 2011;26:325–332

Key words: *alveolar ridge augmentation, bone graft, bone regeneration, bone transplant, endosseous implants, volumetric computed tomography*

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The long-term stability of onlay bone grafts in patients with a thin periodontal biotype is not sufficiently documented. Little is known about the potential long-term influence of periodontal biotype on the maintenance of the volume of block grafts.

Ochsenbein and Ross were the first to describe the normal periodontium as being scalloped and cone-shaped for the anterior interdental architecture versus thicker and spherically shaped for posterior areas.[1] Furthermore, the buccal bony housing was described as commonly thin, versus thick for the palatal bone. Thin buccal tissue was more commonly associated with root fenestrations and dehiscences. In flap surgery, the blood supply was more advantageous on the palatal aspect because of the thicker alveolar process and greater ma rrow spaces, leading to less bone resorption than on the buccal aspect.[2] Tibbetts et al described the "normal relationship of marginal alveolar bone to gingiva," pointing out that different periodontiums within normal limits will invariably present with varying configurations of gingival and bone thicknesses.[3]

Seibert and Lindhe[4] first used the term *periodontal biotype* to describe the thickness of the gingiva in the buccolingual (BL) dimension as being either thick or thin. A number of studies have suggested that teeth with a thin biotype are at higher risk for tissue recession.[5,6] There is also evidence suggesting that, following tooth extraction, significant ridge alterations occur.[7,8] Subjects with a thin biotype could be especially prone to substantial ridge volume loss, resulting in a challenge for the placement of implants and the esthetic outcome. Empirical data suggests that thin tissue is less resistant to trauma, has a compromised vascular network, and renders surgical outcomes less predictable.[2,9–14] In contrast, a thick biotype may promote better blood supply to the underlying osseous structures, affecting the early stages of wound healing.[2,15,16] Flap management may also influence the degree of primary and collateral blood supply to the underlying onlay graft, and ischemia could result from a lack of adequate new angiogenesis if the flap is too thin.[17,18]

A sufficient quantity and quality of bone are prerequisites for successful implant rehabilitation. Maintenance of ridge volume in the anterior sextant is vital for the esthetic success of implant-supported restorations.[19] Patients with atrophied ridges may require hard and soft tissue grafting prior to implant placement. Autogenous block grafting from intraoral sites is a predicable technique for successful reconstruction of ridge defects.[19]

Quasi-experiments are studies that aim to evaluate associations between an intervention (here, bone grafting) and an outcome (ridge augmentation) without randomization. Similar to randomized trials, quasi-experiments aim to demonstrate causality between an intervention and an outcome.[20,21] The present quasi-experimental study aimed to evaluate the functional and esthetic outcome of dental implants placed in the anterior region after block grafting in patients with a thin periodontal biotype. The hypothesis of the present study was that the volume maintenance of block grafts in thin biotype patients may be compromised.

MATERIALS AND METHODS

Fifteen private practice patients with a thin periodontal biotype who were undergoing ridge augmentation in the anterior region prior to implant placement were included in the present study. Enrollment took place between July 2003 and October 2009. All patients had an unremarkable medical history. This study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2000, and all subjects provided informed consent prior to therapy. Ethical approval was obtained from the University of Basque Country Ethics Committee. The sample size (n = 15) was not predetermined for the present study. Historical data are usually used to estimate variances and other parameters in the power function, and there are insufficient historical data in this regard to establish an adequate sample size.[20]

Patients were included in the study on the basis of having insufficient BL ridge width (≤ 4 mm) for implant placement, as assessed on a preoperative computed tomography (CT) scan. Patients with uncontrolled diabetes, a heavy smoking habit (more than half a pack per day), long-term corticosteroid therapy, a history of intravenous bisphosphonate use, uncontrolled hypertension, or other medical conditions contraindicating implant therapy were excluded.

Clinical examination revealed generalized gingival recessions with probing depths ranging from 2 to 3 mm. All 15 patients were diagnosed as having a thin biotype based on the criteria proposed by Oschenbein et al[1,2]: thin, cone-shaped, highly scalloped architecture and existing gingival recessions in the anterior sextant. The presence of buccal bony dehiscences and/or fenestrations was confirmed during surgery in all 15 patients. Donor sites were the mandibular symphysis and ramus. Recipient areas comprised eight single-tooth replacement sites and seven multiple-tooth sites (Table 1; Figs 1a and 1b). All augmentation procedures were performed by the same experienced periodontist (FV).

The same treatment protocol was followed for all patients. Four months after ridge augmentation, implants were placed using a two-stage approach. The implants were uncovered and healing abutments were placed 3 to 6 months after placement. Fixed provisional restorations were placed 4 weeks thereafter. Definitive screw-retained restorations were delivered 1 to 3 months after provisionalization.

Cone beam CT scans (NewTom, QR srl) were obtained at an average of 40 months (Table 1) postaugmentation to document bone levels and healing of the grafts.

Tomographic and Intrasurgical Measurements

In an attempt to standardize repeated measurements, the BL width at the recipient site was measured 7 mm apical to the osseous crest (preoperative) and 5 mm apical to the implant-crown interface (postaugmentation). The preoperative and postoperative BL widths were then compared (Table 1). All measurements were done by the same calibrated examiner (KS). Because each cross-sectional cut on the CT scan was 1 mm apart, the midline was used as the reference point and the same cross-sectional cut was used for preaugmentation and postaugmentation calculations,

Table 1 Descriptive Analysis

Patient	Age (y)	Gender	Recipient site(s)	Donor site	Follow-up (mo)	Recipient baseline*	Block thickness	Recipient postop (%)*	Implant size (mm)
1	30	M	Lateral incisors	Chin	35	3	6	9.0 (100)	4 × 13
2	42	M	R central	Chin	56	4	4.5	8.1 (95)	4 × 15
3	40	F	L lateral	Ramus	37	2.5	3.5	5.7 (95)	4 × 13
4	32	M	R central	Ramus	47	3	3.5	6.0 (92)	4 × 11.5
5	46	M	R central	Chin	35	1.5	6.5	8.0 (100)	3.25 × 13
6	57	F	Lateral incisors	Ramus	38	3.5	3	6.3 (97)	4 × 13
7	27	F	L lateral and canine	Ramus	35	3.3	3	6.0 (95)	3.25 × 13
8	69	M	R central	Chin	41	3.5	6.5	9.6 (96)	4 × 11.5
9	37	F	L central	Chin	45	3	4	7.0 (100)	4 × 11.5
10	36	F	L canine	Ramus	33	4	3.5	7.2 (96)	4 × 13
11	35	F	Lateral incisors	Ramus	32	3.6	3.5	7.0 (99)	4 × 13
12	68	F	R central, L lateral	Ramus	26	4	3	6.9 (99)	4 × 13
13	52	F	L lateral	Chin	72	3	6	9.0 (100)	4 × 13
14	25	F	Lateral incisors	Chin	28	3.5	5	8.0 (94)	4 × 13
15	53	F	Lateral incisors	Ramus	42	3.8	3.4	7.0 (97)	4 × 13
Average	43				40	3.3	4.3	7.4 (97)	

All sites were in the maxilla, except for patient 5.
*Baseline and postoperative BL thickness at recipient site (mm). Recipient postoperative % = volume maintained after follow-up.

Figs 1a and 1b Preoperative anterior views of two thin-biotype patients (*left*: patient 5, *right*: patient 12).

with a margin of error of 0.5 mm. At the beginning of the study, the examining clinician underwent a period of training to achieve a reproducibility of 98% for all linear measurements to within 0.5 mm.

In addition, the thickness of the symphysis and ramus block grafts harvested was recorded intrasurgically (Table 1) using calipers immediately before fixation of the grafts.

Surgical Technique

The onlay grafting technique has been described elsewhere[22,23] and is shown in Figs 2 and 3. Briefly, flap management was performed as follows. Sulcular incisions were done for the anterior sextant teeth (canine to canine in either arch) and connected with two vertical incisions. A full-thickness mucoperiosteal flap was raised and continued past the mucogingival junction (Fig 2). Recipient sites were prepared with intramarrow penetrations (buccal cortical perforations) only on patient 5. A one- or two-piece block graft was harvested from the mandibular symphysis or ramus and fixated to the recipient site with one or two miniscrews (Ace Surgical) (Figs 3a to 3d). Osseous particles were collected with a bone scraper (Biomet 3i) to fill in any voids (Figs

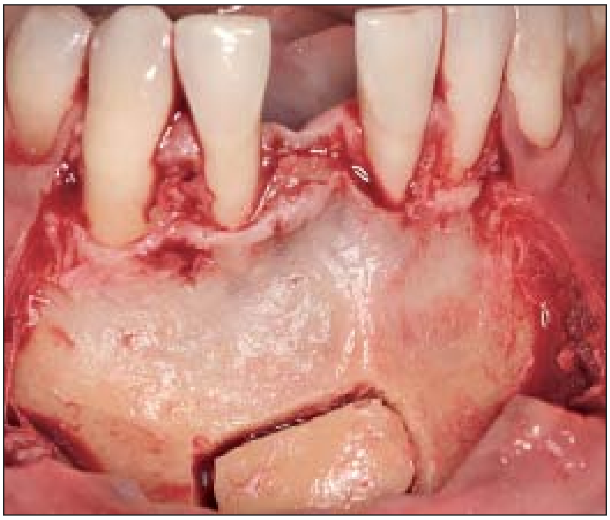

Fig 2 Recipient site in patient 5 before augmentation. A flap is extended from canine to canine.

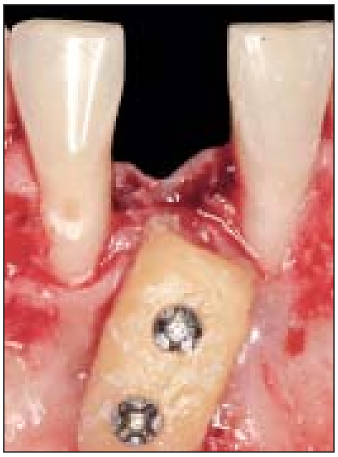

Fig 3a A symphyseal block is fixated with two miniscrews in patient 5.

Fig 3b Bone particles are used to fill in any voids after block fixation.

Fig 3c A noticeable discrepancy is present between the augmented site and the alveolar housing of adjacent teeth.

Fig 3d Intraoperative view of patient 12. Ramus blocks have been fixated, and particulate bone fills the voids.

Fig 3e Graft sites 4 months later in patient 12.

Figs 4a *(Left)* **and 4b** *(Above)* Implants were placed immediately after the miniscrews were removed.

Fig 5a *(Left)* Definitive screw-retained restorations on patient 5 at 42 months.

Fig 5b *(Above)* Definitive fixed partial denture restoration on patient 12 at 26 months.

3b to 3d). Flaps were released with sharp dissection to allow tension-free closure. Interrupted sutures were used to close the flap. After 4 months of healing (Fig 3e), the fixation screws were removed and endosseous implants placed (Figs 4a and 4b). Fixed provisional restorations were placed 3 to 6 months after implant placement. Definitive screw-retained restorations were delivered 4 months later (Figs 5a and 5b).

Clinical Assessment

The patients were examined annually, both clinically and radiographically. The incisal edge of the implant crown was used as a reference point to measure mucosal recession at the buccal aspect of each augmented site. Measurements were made at the time of crown delivery and at the final follow-up appointment. Moreover, implant transparency, ie, any visibility of the implant or abutment through the soft tissue, was assessed clinically and confirmed using digital photography.[24]

Statistical Analysis

Descriptive data were expressed as means ± standard deviations. A commercially available software program (SPSS, version 14, IBM) was used to compare average BL thickness and to create box plots. The Student *t* test was used for paired observations to analyze values of BL width at baseline and after augmentation. Statistical significance was set at $P < .05$.

RESULTS

Fifteen subjects (5 men and 10 women) with an average age of 43.3 ± 14 years (range, 25 to 69 years) entered this study. Periapical radiographs (Fig 6) and a control CT scan were taken at an average of 40 ± 11.6 months (range, 26 to 72 months) after ridge augmentation to evaluate the long-term outcome (Fig 7). The average block thickness was 4.3 ± 1.3 mm (range, 3.0 to 6.5 mm).

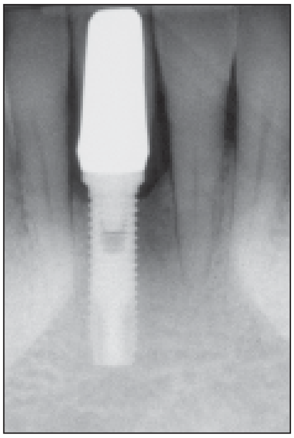

Fig 6 Patient 5. Final periapical radiograph of the implant in the mandibular right central incisor site at 35 months.

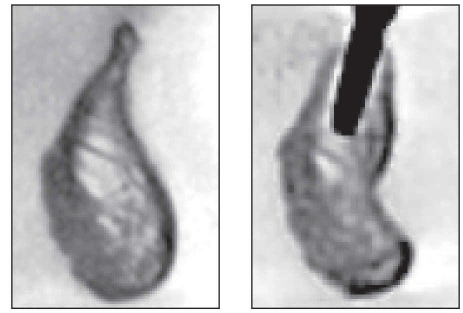

Fig 7 Preoperative cross-sectional CT image of patient 5 *(left)*. Postaugmentation cross-sectional CT image of patient 5 at 35 months showing augmented recipient site and donor site bone repair *(right)*.

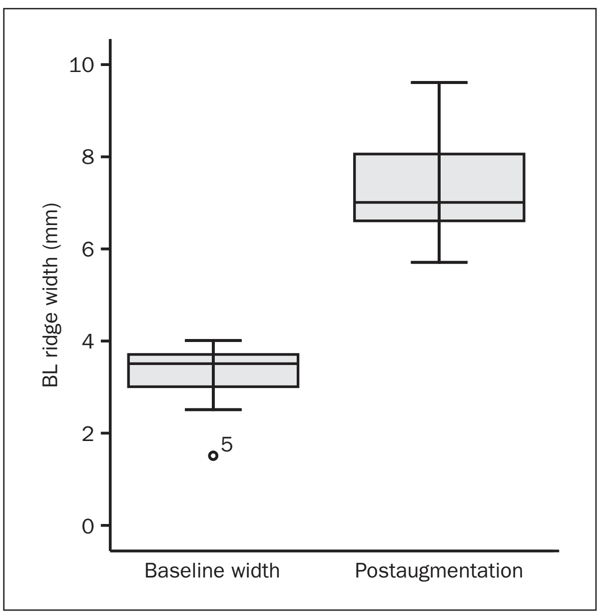

Fig 8 Box plot depicting the significant difference in BL width ($P < .0001$) preoperative and postoperative.

As shown by CT scans, the average recipient BL width was 3.3 ± 0.7 mm (range, 1.5 to 4.0 mm) at baseline and 7.4 ± 1.2 mm after an average of 3.3 years postaugmentation (Table 1; Fig 7). The difference between preoperative and postoperative BL width was statistically significant ($P < .0001$; 95% confidence interval: 3.4 to 4.9 mm) (Fig 8). The average augmentation per site was 2.2 times the initial BL width, and an average of 97% of the augmented width was maintained after 40 months. Clinical preoperative and postoperative measurements showed absence of buccal mucosal recession at the recipient sites in all 15 individuals ($P > .05$). Digital photographs taken at yearly intervals confirmed the absence of mucosal recession and implant transparency in all 15 subjects. The functional and esthetic condition of all patients has been stable for the period of time followed.

DISCUSSION

The present study demonstrated the long-term volume maintenance of block grafts in 15 augmentation patients with thin periodontium. The clinical examinations revealed absence of implant transparency through soft tissues and no mucosal recessions at an average of 40 months (Figs 5a and 5b). Moreover, the tomographic evaluation 3.3 years after block grafting validates the hypothesis that thin periodontal biotype may have limited or no influence on the healing and stability of transplanted bone.[19] Endosseous implants were placed 4 months after augmentation and, for the duration of the study, the grafted sites maintained significantly higher bone volume than the alveolar frame of the adjacent teeth. Implants were loaded at an average of 9 to 10 months after grafting, and this may have enhanced bone maintenance and osseointegration, as shown in an animal study by Berglundh et al.[25]

One way to assess osseous volume gain after grafting is surgical re-entry. However, this invasive technique, which offers no benefit to the patient, raises serious ethical questions. The method employed in the present study, CT, has been used as a noninvasive, precise procedure, thus allowing for quantitative evaluation of osseous volumetric changes in endochondral and intramembranous transplants.[19,21–23,25–30] Buchman et al[27] used micro-CT for the evaluation of membranous bone in an animal model. The technique was highly accurate in measuring changes in bone stereology, bone volume, and microarchitecture. Other authors have suggested that the accuracy and reproducibility of caliper or cephalometric measurements may be questionable due to bone irregularities and human error.[27–29] The clinical applications of CT scans are multiple, and the technique can aid in diagnosis and treatment planning prior to implant placement, as well as assessment of regenerative therapy outcomes.[30,31]

Some authors have expressed concern that a thin periodontal biotype may compromise collateral blood supply and impair wound healing, and have suggested that thick flaps might promote better circulation to the underlying osseous structures, assisting in the initial stages of healing.[15–18] Indeed, rapid vascularization of the block graft is paramount for successful neo-osteogenesis.[32] Cortical transplants seem to be penetrated by blood vessels in as little as 6 days and completely revascularized in 1 to 2 months.[33,34]

It would seem reasonable to expect a greater loss of bone volume in patients who present a highly scalloped architecture, bone dehiscence, or fenestrations compared to patients with a thick, flat architecture. Also, one could speculate that a patient's genotype would induce more pronounced changes, in terms of volume loss, in thin-biotype patients, to compensate for the osseous architecture of the adjacent teeth. Thus, the biotype of adjacent teeth could dictate the degree of volume loss at the transplanted site. However, in this study of thin-biotype patients, CT scans (obtained at average of 40 months postaugmentation) demonstrated that approximately 97% of the augmented BL width was maintained (Fig 7b). Hence, a thin periodontal biotype did not seem to have an effect on the volume integrity of the augmented sites, suggesting that the underlying recipient periosteal and marrow blood supply may be sufficient for the healing of the transplanted bone.

Contradictory results have been reported on the effect of barrier membrane coverage of block grafts.[35,36] One study concluded that onlay bone graft volume is maintained better when the graft is covered with a resorbable membrane.[36] However, the results of the present study question the advantage of barrier membranes on onlay grafts. Recent research has suggested that periosteal preservation is as effective as a barrier membrane in protecting combined particulate/block grafts in advanced human critical-size defects.[37,38]

With autogenous bone grafting, morbidity at the donor site is a concern. The mandibular symphysis is an excellent source for harvesting block grafts and provides good access.[21,22] However, postoperative complications, such as altered sensation or paresthesia, have been reported. In a long-term retrospective examination of 60 patients who underwent symphysis harvesting, Weibull et al[39] reported 7.6% impaired soft tissue tactility and sensitivity and 1% apical pathology. Cephalometric evaluation of the donor site in a subgroup of 45 patients showed good remineralization in 42 patients (93.3%). Complications following ramus harvesting are less common and include paresthesia of the facial mucosa related to buccal nerve injury.[40] Three patients from the present study reported altered sensation of the buccal gingiva up to the fourth month. This altered sensation, categorized as hypoesthesia,[41] was transient and resolved by the fifth month. No apical pathology around the mandibular teeth was detected at 40 months.

The normal cascade of physiologic healing events in response to injury might have favored donor site bone repair. This process was proposed by Frost[42] as a regional accelerated phenomenon of increased bone turnover in response to noxious stimuli.

Whereas a large, randomized sample size would have given this research higher statistical power to establish causality, the nature of the present study did not afford such a luxury. As proposed by Harris et al,[20] when it is known that only a small sample size will be available to test the efficacy of an intervention, randomization may not be a viable option and a quasi-experimental design[21] can be used. Randomization is beneficial because it tends to evenly distribute both known and unknown confounding variables. However, researchers often choose not to randomize an intervention for such reasons as ethical considerations, difficulty of randomizing subjects, or a small available sample size.[21]

Further investigation is warranted to evaluate osseous repair after harvesting[21] and whether bone substitutes are indeed necessary to foster bone regeneration at the donor site.

CONCLUSIONS

Within the limitations of the present study, autogenous osseous transplants can predictably restore function and esthetics of anterior ridge defects and appear to maintain long-term stable bone volume around endosseous implants, regardless of a thin periodontium. A thin periodontal biotype did not significantly affect the volume integrity of adjacent transplanted grafts in the present patient population.

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REFERENCES

1. Ochsenbein C, Ross S. A reevaluation of osseous surgery. Dent Clin North Am 1969;13:87–102.
2. Ochsenbein C, Bohannan HM. The palatal approach to osseous surgery I. Rationale. J Periodontol 1963;34:60–68.
3. Tibbetts LS, Ochsenbein C, Loughlin DM. Rationale for the lingual approach to mandibular osseous surgery. Dent Clin North Am 1976;20:61–78.
4. Seibert J, Lindhe J. Esthetics and periodontal therapy. In: Lindhe J (ed). Textbook of Clinical Periodontology, ed 3. Copenhagen: Munksgaard, 1997:647–681.
5. Weisgold A. Contours of the full crown restoration. Alpha Omegan 1977;7:77– 89.
6. Olsson M, Lindhe J. Periodontal characteristics in individuals with varying form of the upper central incisors. J Clin Periodontol 1991;18:78–82.
7. Araújo MG, Lindhe J. Ridge alterations following tooth extraction with and without flap elevation: An experimental study in the dog. Clin Oral Implants Res 2009;20:545–549.
8. Araújo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. J Clin Periodontol 2005;32:212–218.
9. Wennstrom J, Lindhe J. Plaque-induced gingival inflammation in the absence of attached gingiva in dogs. J Clin Periodontol 1983;10:266–276.
10. Wennstrom J, Lindhe J. Role of attached gingiva for maintenance of periodontal health. Healing following excisional and grafting procedures in dogs. J Clin Periodontol 1983;10:206–221.
11. Serino G, Wennstrom JL, Lindhe J, Eneroth L. The prevalence and distribution of gingival recession in subjects with a high standard of oral hygiene. J Clin Periodontol 1994;21:57–63.
12. Matter J. Creeping attachment of free gingival grafts. A five-year follow-up study. J Periodontol 1980;51:681–685.
13. Muller HP, Heinecke A, Schaller N, Eger T. Masticatory mucosa in subjects with different periodontal phenotypes. J Clin Periodontol 2000;27:621–626.
14. Kois JC. Predictable single-tooth peri-implant esthetics: Five diagnostic keys. Compend Contin Educ Dent 2004;25:895–906.
15. Kennedy JE. Effect of inflammation on collateral circulation of the gingiva. J Periodontal Res 1974;9:147–152.
16. Wilderman MN, Pennel BM, King K, Barron JM. Histogenesis of repair following osseous surgery. J Periodontol 1970;41: 551–565.
17. Egelberg J. The blood vessels of the dento-gingival junction. J Periodontal Res 1966;1:163–179.
18. Kindlova M. The development of the vascular bed of the marginal periodontium. J Periodontal Res 1970;5:135–140.
19. Verdugo F, Simonian K, Nowzari H. Periodontal biotype influence on the volume maintenance of onlay grafts. J Periodontol 2009;80:816–823.
20. Harris AD, McGregor JC, Perencevich EN, et al. The use and interpretation of quasi-experimental studies in medical informatics. J Am Med Inform Assoc 2006;13:16–23.
21. Verdugo F, Simonian K, D'Addona A, Pontón J, Nowzari H. Human bone repair after mandibular symphysis block harvesting: A clinical and tomographic study. J Periodontol 2010;81:702–709.
22. Verdugo F, Simonian K, Smith McDonald R, Nowzari H. Quantitation of mandibular symphysis volume as a source of bone grafting. Clin Implant Dent Relat Res 2010;12:99–104.
23. Verdugo F, Simonian K, Smith McDonald R, Nowzari H. Quantitation of mandibular ramus volume as a source of bone grafting. Clin Implant Dent Relat Res 2009;11:e32–e37.
24. Varkey P, Tan NC, Girotto R, Tang WR, Liu YT, Chen HC. A picture speaks a thousand words: The use of digital photography and the Internet as a cost-effective tool in monitoring free flaps. Ann Plast Surg 2008;60:45–48.
25. Berglundh T, Abrahamsson I, Lindhe J. Bone reactions to longstanding functional load at implants: An experimental study in dogs. J Clin Periodontol 2005;32:925–932.
26. Lu M, Rabie AB. Quantitative assessment of early healing of intramembranous and endochondral autogenous bone grafts using micro-computed tomography and Q-win image analyzer. Int J Oral Maxillofac Surg 2004;33:369–376.
27. Buchman SR, Sherick DG, Goulet RW, Goldstein SA. Use of microcomputed tomography scanning as a new technique for the evaluation of membranous bone. J Craniofac Surg 1998;9:48–54.
28. Feldcamp LA, Goldstein SA, Parfitt AM, Jesion G, Kleerekoper M. The direct examination of three-dimensional bone architecture in vitro by computed tomography. J Bone Miner Res 1989;4:3–11.
29. Kuhn JL, Goldstein SA, Feldkamp LA, Goulet RW, Jesion G. Evaluation of a microcomputed tomography system to study trabecular bone structure. J Orthop Res 1990;8:833–842.
30. Ito K, Yoshinuma N, Goke E, Arai Y, Shinoda K. Clinical application of a new compact computed tomography system for evaluating the outcome of regenerative therapy: A case report. J Periodontol 2001;72:696–702.
31. Bhatavadekar NB, Paquette DW. Long-term follow-up and tomographic assessment of an intrabony defect treated with enamel matrix derivative. J Periodontol 2008;79:1802–1808.
32. Albrektsson T. Repair of bone grafts. A vital microscopic and histologic investigation in the rabbit. Scand J Plast Reconstr Surg 1980;14:1–12.
33. Fonseca RJ, Clark PJ, Burkes EJ Jr, Baker RD. Revascularization and healing of onlay particulate autologous bone grafts in primates. J Oral Surg 1980;38:572–577.
34. Kusiak JF, Zins JE, Whitaker LA. Early revascularization of intramembranous bone. Plast Reconstr Surg 1985;76:510–516.
35. Dongieux JW, Block MS, Morris G, Gardiner D, Dean K. The effect of different membranes on onlay bone graft success in the dog mandible. Oral Surg Oral Med Oral Pathol 1998;86: 145–151.
36. Adeyemo WL, Reuther T, Bloch W, et al. Healing of onlay mandibular bone grafts covered with collagen membrane or bovine bone substitutes: A microscopical and immunohistochemical study in the sheep. Int J Oral Maxillofac Surg 2008;37:651–659.
37. Verdugo F, D'Addona A, Ponton J. Clinical, tomographic and histological assessment of periosteal guided bone regeneration with cortical perforations in advanced human critical size defects. Clin Implant Dent Relat Res 2010 May 11 [epub ahead of print].
38. Verdugo F, Frydman A, Castillo A, Ponton J, Nowzari H. Long term onlay graft volume maintenance in aggressive periodontitis. Int J Periodontics Restorative Dent (in press).
39. Weibull L, Widmark G, Ivanoff CJ, Borg E, Rasmusson L. Morbidity after chin bone harvesting: A retrospective long-term follow-up study. Clin Implant Dent Relat Res 2009;11:149–157.
40. Clavero J, Lundgren S. Ramus or chin grafts for maxillary sinus inlay and local onlay augmentation: Comparison of donor site morbidity and complications. Clin Implant Dent Relat Res 2003;5:154–160.
41. Walter JM, Gregg JM. Analysis of postsurgical neurologic alteration in the trigeminal nerve. J Oral Surg 1979;37:410–414.
42. Frost HM. The biology of fracture healing: An overview for clinicians. Clin Orthop 1989;248:283–309.