CLINICAL ORAL IMPLANTS RESEARCH

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Analysis of the socket bone wall dimensions in the upper maxilla in relation to immediate implant placement

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Abstract

Background: Animal and human researches have shown that immediate implant placement into extraction sockets failed to prevent socket dimensional changes following tooth extraction. It has been suggested that a minimal width of 1–2 mm of buccal bone is necessary to maintain a stable vertical dimension of the alveolar crest.

Aim: To determine the dimensions of the bony wall at extraction sites in the esthetic zone (anterior teeth and premolars in the maxilla) and relate it to immediate implant placement.

Methods: As part of an ongoing prospective randomized-controlled multicenter clinical study on immediate implant placement, the width of the buccal and palatal bony walls was recorded at 93 extraction sites.

Results: The mean width of the buccal and palatal bony walls was 1 and 1.2 mm, respectively ($P<0.05$). For the anterior sites (canine to canine), the mean width of the buccal bony wall was 0.8 mm. For the posterior (premolar) sites, it was 1.1 mm ($P<0.05$). In the anterior sites, 87% of the buccal bony walls had a width ≤ 1 mm and 3% of the walls were 2 mm wide. In the posterior sites, the corresponding values were 59% and 9%, respectively.

Conclusions: If the criterion of a minimal buccal bone width of 2 mm to maintain a stable buccal bony wall is valid, only a limited number of sites in the anterior maxilla display such a clinical situation. The data suggested that in the majority of extraction sites in the anterior maxilla, thin (≤ 1 mm) buccal walls were present. This, in turn, means that in most clinical situations encountered, augmentation procedures are needed to achieve adequate bony contours around the implant.

The success of dental implant treatment of partially and fully edentulous patients has been documented extensively (Karoussis et al. 2003; Romeo et al. 2004, 2006; Wennström et al. 2004, 2005). Biological understanding of soft and hard tissue healing around implants, development of new implant surfaces and designs and development of advanced surgical techniques have allowed the extension of routine indications for implant therapy with increasing predictability and better prognosis.

One such indication is the immediate placement of implants into extraction sockets. This healing pattern was termed 'Type 1' implant installation at a consensus conference (Hämmerle et al. 2004).

From a patient's perspective, fewer surgical procedures are needed and the overall treatment time is reduced. From the practitioner perspective, an optimal availability of the bone was attained. On the other hand, disadvantages for this procedure were also realized. Because of the discrepancy between the tooth/root anatomy and

the design of dental implants, the resulting lack of congruence between the implant bed and the alveolus of an extracted tooth may represent a more challenging situation for the surgical procedure when compared with that of a healed site (Botticelli et al. 2006). Moreover, the potential lack of keratinized mucosa may negatively affect flap adaptation and situations with thin tissue biotypes may compromise optimal treatment outcomes especially in areas of esthetic priority. Therefore, immediate implant placement was defined as a technique-sensitive procedure (Hämmerle et al. 2004).

It has been suggested that immediate placement of implants into extraction sockets may preserve the bony architecture (Denissen & Kalk 1991; Denissen et al. 1993; Sclar 1999). However, recent animal studies have clearly established that following tooth extraction, the buccal and lingual walls of the alveolus undergo substantial resorption (Araujo & Lindhe 2005; Cardaropoli et al. 2005). Belonging to the periodontal structures embryologically, the bundle bone was resorbed completely as a result of a lack of supporting function of the tooth following its extraction. Because the thin buccal wall is predominantly composed of bundle bone, its resorption had to result in a vertical reduction of the buccal bony crest. However, for the wider lingual crest that is also comprised of substantial proportions of lamellar bone, less vertical reduction was observed. Moreover, resorption occurred on the outer surfaces of both bony walls (Araujo & Lindhe 2005). Subsequently, the same authors demonstrated that immediate implant placement into extraction sockets was not able to prevent this remodelling process, and hence could not prevent resorption of the buccal bony wall following tooth extraction (Araújo et al. 2005). Recent clinical studies have confirmed that implants placed immediately into extraction sockets will not prevent the occurrence of ridge alterations (Botticelli et al. 2004a, 2004b; Covani et al. 2004; Ferrus et al. 2009; Sanz et al. 2009).

Factors affecting the remodelling process of the buccal and lingual bony walls of extraction sockets are still uncertain. However, the analysis of a recent study (Ferrus et al. 2009; Tomasi et al. 2009) has revealed that the width of the buccal bony wall may have a significant influence in determining its resorption pattern.

The minimal buccal width required to avoid vertical crestal resorption has yet to be established. In a clinical study (Spray et al. 2000) of implant placement into healed sites, facial bone thickness was determined at the time of implant installation and after a healing period of 3–6 months using calipers. Significantly greater facial bone loss was observed as the facial bone thickness decreased. Sites with >3 mm of bone loss showed the lowest mean facial bone thickness (1.3 mm). Conversely, sites exhibiting no change in facial bone response had a mean thickness of 1.8 ± 1.10 mm at implant installation. It was concluded that the critical thickness of the facial bone plate to reduce facial bone loss was around 2 mm.

The healing dynamics at buccal periimplant sites in relation to the dimensions of the alveolar ridges were evaluated in a dog model (Qahash et al. 2008). Fluorescent bone labelling revealed that the extent of buccal bone resorption was associated with the width of the alveolar ridge. This association was nonlinear and a 2 mm threshold accounted for this nonlinearity. This association was two times greater when the buccal alveolar ridge was <2 mm compared with greater width. It was concluded that the buccal alveolar ridge width should be at least 2 mm wide if the alveolar bone level on the facial aspect was to be maintained.

In a recent publication by a panel of experts and master clinicians in the field of implantology, clinical guidelines were elaborated for implant placement in the esthetic anterior healed sites. Once the implant osteotomy site was performed, an ideal buccal bone width of 2 mm was recommended to achieve an optimal biological and esthetic outcome (Belser et al. 2007).

Thus, based on very few studies and a general consensus, the scientific community seems to agree that ideally a minimum of 2 mm of buccal bone wall is mandatory once the implant bed has been prepared in a healed site to ensure proper soft tissue support and avoid the resorption of the facial bone wall following restoration. If this minimal requirement is not met, then the augmentation ridge procedure (before or at implant placement) should be performed to obtain this minimal dimension (Belser et al. 2007).

When placing implants in fresh extraction sockets, it would be of interest to know the anatomical dimensions of the socket walls and how often they actually meet what is considered to be the minimal requirement, i.e. 2 mm of buccal bone width.

Hence, the aim of the present work was to measure and analyze the dimensions of the bone walls at 93 consecutive implants placed immediately following tooth extraction.

Material and method

The data presented in this report were part of an ongoing prospective multicenter randomized clinical trial with the aim to evaluate buccal bone preservation using fixture Microthread™ and OsseoSpeed™ (Astra Tech AB, Mölndal, Sweden) implants immediately placed into extraction sockets in the maxilla.

In brief, 93 patients in need of implant therapy replacing anterior tooth/teeth to be extracted in the maxilla (i.e. teeth 15–25) were screened for potential inclusion in the study.

Patients with uncontrolled periodontal disease, caries, current alcohol or drug abuse, systemic, local conditions and medication that would interfere with wound healing or osseointegration, a history of radiotherapy in the head and neck region and a history of chemotherapy were excluded from the study.

Patients who were smokers were not excluded, but had to limit their cigarette consumption to 10 cigarettes a day from the day of extraction and implant placement until the re-entry procedure at 16 weeks after implant placement.

Once the patient was enrolled in the study, extraction of the tooth and implant placement were scheduled. At the time of surgery, after the tooth had been removed and the remaining socket was considered as suitable for immediate implant placement, intra-operative measurements of the socket, including the width of the buccal and palatal walls of the sockets (Fig. 1a and b), were recorded. The width was measured 1 mm apical to the alveolar crest level.

Then, the randomly allocated implant type was placed and the size of the defect

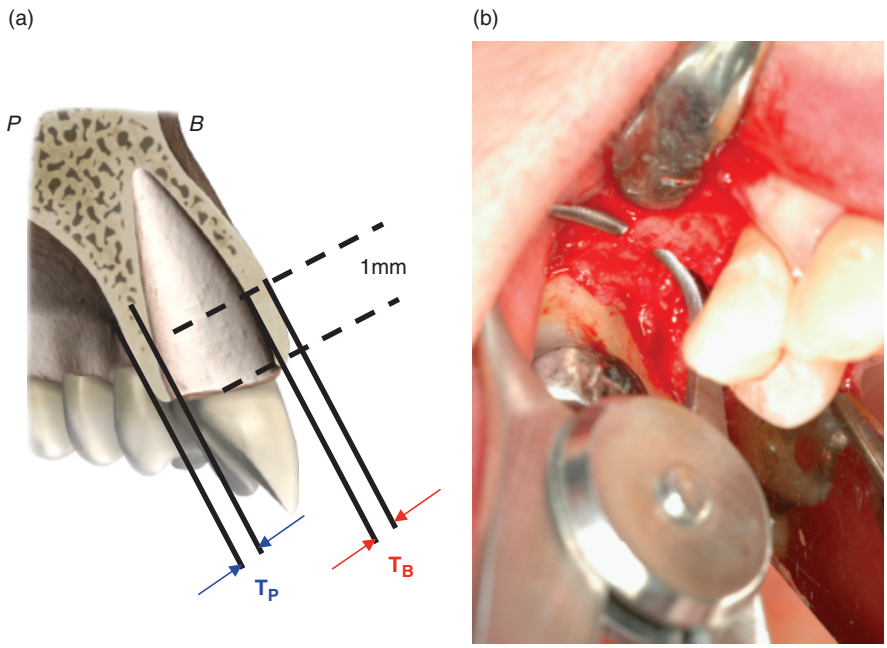

Fig. 1. Measurement of the width of the palatal and buccal socket walls (a) applying calipers (b).

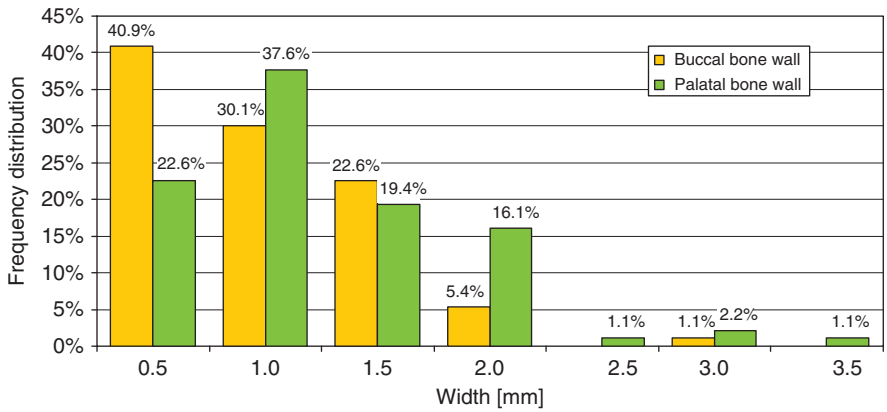

Fig. 2. Frequency distribution of the widths of the buccal and palatal bony walls.

around the implants was recorded. A re-entry procedure was performed 16 weeks after implant placement, enabling the operator to record the same measurement as at the time of implant placement. Twenty-two weeks after implant installation, the implant was loaded.

For the present report, the mean values and standard deviations were calculated and used to compare the width of the palatal and buccal bony walls. A subset analysis was performed to split the findings between the anterior sites, including extractions sites from canine to canine, and the posterior sites encompassing premolar sites. An independent *t*-test was used to assess the differences between buccal and palatal sites as well as between anterior and posterior sites. Values of $P<0.05$ were accepted as statistically significant.

Results

Overall, 93 implants were immediately placed into extraction sockets. The mean width of the buccal and palatal bony walls was 1 mm (range: 0.5–3 mm, SD 0.5 mm) and 1.2 mm (range: 0.5–3.5 mm, SD 0.6 mm), respectively. This difference was statistically significant ($P=0.004$) using independent *t*-tests.

Figure 2 presents the frequency distribution of the various widths of the buccal and palatal bony walls. It is obvious that the frequency distribution curve of the palatal bony wall width is shifted to the right as compared with the one for the buccal bony wall width, indicating a wider bony plate on the palatal aspect.

The vast majority of the buccal bony walls (71%) had a width of 0.5–1 mm. Only 6.5% of the buccal walls displayed a width of 2 mm or more. For the palatal bony walls, the vast majority (60.2%) had a width within 0.5–1 mm as well. However, a width of 2 mm or more was a common finding (20.5%).

On the buccal aspect, 0.5 mm wide walls represented the most often encountered value (40.9% of the sites).

A subset analysis performed to discriminate anterior (canine to canine) and posterior sites (premolars) showed a mean width of the buccal bony wall of 0.8 mm (range: 0.5–2 mm, SD 0.4 mm) for the anterior sites. The corresponding value for the posterior sites was 1.1 mm (range: 0.5–3 mm, SD 0.5 mm). This difference was statistically significant ($P=0.0002$). For the palatal bone width, the mean width in the anterior sites was 1.2 mm (range: 0.5–3.5, SD 0.7 mm) compared with 1.3 mm (range: 0.5–3.5, SD 0.6 mm) for the posterior sites. This difference, however, did not reach statistical significance ($P=0.5$).

Figure 3 presents a frequency distribution of the various widths of the buccal bony walls of anterior and posterior sites, respectively. Similar to the frequency distribution curves of the buccal and palatal bone wall width, there was an obvious shift to the right for the frequency distribution curve of the posterior buccal bone wall width, illustrating the fact that maxillary anterior sites have, overall, a thinner buccal wall than do posterior sites.

In the anterior sites, a vast majority of the buccal bony walls (87.2%) had a width $\leq$ 1 mm, and only 2.6% of the walls were 2 mm wide. In the posterior sites, 59.3% of the buccal walls were $\leq$ 1 mm wide and 9.3% were $\geq$ 2 mm wide.

Discussion

It has been clearly established that immediate implant placement cannot prevent dimensional changes of the alveolar ridge (Botticelli et al. 2004a, 2004b; Covani

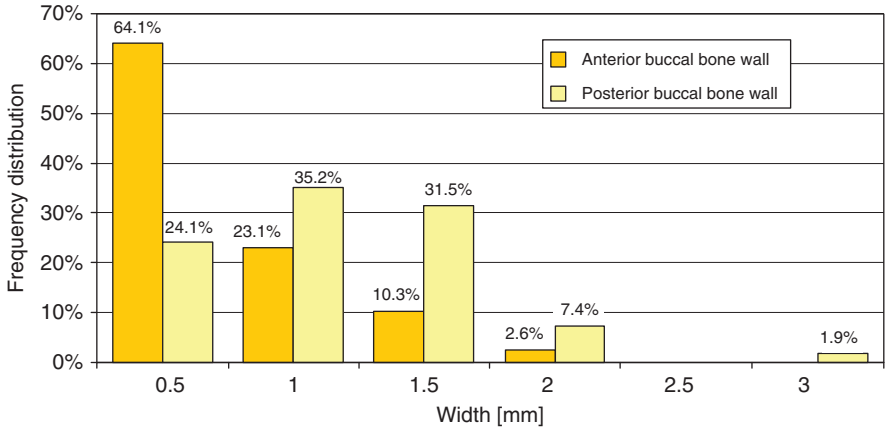

Fig. 3. Frequency distribution of the width of the anterior and posterior buccal bony walls.

et al. 2004; Araújo et al. 2005) following tooth extraction (Pietrokovski 1975; Schropp et al. 2003; Araújo & Lindhe 2005). However, dimensional changes may be predicted (Tomasi et al. 2009) on the basis of the defect size and configuration resulting from tooth extraction.

In this respect, the dimensions of the residual buccal bony wall have gained significance.

While there is general agreement among clinicians that a minimal width of 2 mm of the buccal bony wall is a prerequisite to maintain the vertical dimension of the alveolar crest (Spray et al. 2000; Belser et al. 2007; Qahash et al. 2008), the present analysis of data from a multicenter randomized-controlled clinical trial has shown that the buccal bony wall was significantly thinner than the palatal bony wall. This is in agreement with the results of a previous clinical trial (Botticelli et al. 2004a, 2004b). That study, as opposed to the present one, included mandibular sites as well.

In the context of immediate implant placement, the width of the buccal bone wall is definitely of interest. However, one measurement of concern is the gap distance between the implant and the bone wall socket. Indeed, this situation may be encountered because the dimensions of a tooth can be greater than the dimensions of the implant. Animal studies have shown that a gap of 1–2.25 mm at the time of implant placement in healed sites could be readily filled when allowed to heal for 4 months and using rough implant surfaces (Botticelli et al. 2003, 2004a, 2004b). However, resorption of some marginal bone tissue was reported and these values were consistently higher for the buccal site as compared with mesial, distal and lingual sites (Botticelli et al. 2004a, 2004b). The healing pattern was even less favorable when implants were placed in fresh extraction sockets. Botticelli et al. (2006) compared the healing of implants placed in a surgically created self-contained defect with that of implants placed in a fresh extraction socket. The four-wall self-contained defect healed almost completely with *de novo* bone formation with the bone crest close to the abutment/fixture junction. Conversely, the crestal bone level at the implant placed in the fresh extraction socket underwent marked resorption, and after a 4-month healing period, the crest was located roughly 3 mm below the abutment/fixture junction on the buccal site.

This demonstrates that, in dogs, the defect resolution patterns of surgically created sites or fresh extraction sites are not comparable.

In humans, Wilson et al. (1998) showed that small gaps, i.e. not exceeding 1.5 mm, at the immediate implant placement site could heal without the placement of a membrane. Paolantonio et al. (2001) showed that for implants placed in fresh extraction sockets, bone-to-implant gaps of ≤ 2 mm healed to the same extent in terms of the degree of osseointegration when compared with healed sites. However, it has to be mentioned that none of these human studies reported on the remaining bone wall width and dimensional changes of the ridge.

More recently, Chen et al. (2007) placed 30 implants in maxillary anterior extraction sockets in 30 patients. The gap between the implant and the socket bone wall (mean value: 1.9 mm) was randomly assigned to receive anorganic bovine bone with or without a bioresorbable collagen membrane or no graft. The authors showed that, when compared with no graft, anorganic bovine bone was able to limit horizontal ridge resorption but not the vertical resorption of the buccal bone wall. They also suggested that the extent of vertical crestal resorption is related to the initial thickness of the buccal crestal bone. In one-third of the sites, the buccal mucosa receded and led to suboptimal esthetic outcomes in eight cases out of 30 (26.7%). Interestingly, this outcome was associated with a shorter distance between the implant shoulder and the internal socket bone wall. Therefore, the authors suggested that when implants are placed in an extraction socket, the implant shoulder should be positioned at least 2 mm from the internal buccal socket wall.

Other studies (Simon et al. 2000; Iasella et al. 2003) have demonstrated that the vertical resorption could be limited by overbuilding the contour of the ridge. In order to achieve this, graft material would be laid on the coronal part and on the buccal aspect of the external side of the socket.

At present, the assumption is made that maintenance of the crestal buccal bone will allow a better optimal soft tissue level and stability. However, the relationship between bone remodelling after implant placement and soft tissue stability is not well understood. No predictable pattern of soft tissue changes following implant installation has been identified so far (Oates et al. 2002; Belser et al. 2004).

Taken all together, the current knowledge shows that implant placement cannot prevent the occurrence of dimensional ridge changes following tooth extraction. The buccal bone wall width is an important factor in determining the amount of vertical crestal resorption following extraction. In a healed site, a minimal width of 2 mm has been suggested in order to maintain the crest around an implant. It can be speculated that in the case of immediate implant placement, an even greater width would be needed to account for the dimensional changes following tooth extraction. A gap of 1.5–2 mm between the implant and the socket bone walls can readily heal

without compromising the degree of osseointegration; however, some vertical resorption of the buccal bone wall cannot be excluded. In order to compensate for the ridge dimensional changes, grafting of the socket and of the outer part of the socket has been suggested. It has to be kept in mind that the soft tissue changes in relation to bone remodelling remain unclear.

The present study indicates that only a minority (6.5%) of the maxillary teeth including incisors, canine and premolars have a buccal bone wall width of 2 mm or more. When incisors and canine were considered, then, only one site out of 39 (2.6%) displayed a 2 mm wide crestal buccal bone. Therefore, if the criterion of a minimal buccal bone width of 2 mm to maintain a stable buccal bony wall is valid, only a limited number of sites in the anterior maxilla represent such a clinical situation. This in turn might mean that in most situations, when immediate implants are considered in esthetic sites, auxiliary procedures, such as guided bone regeneration, may be needed to achieve adequate bone contour around the implant and optimal esthetic outcome.

References

Araújo, M.G. & Lindhe, J. (2005) Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *Journal of Clinical Periodontology* **32**: 212–218.

Araújo, M.G., Sukekava, F., Wennstrom, J.L. & Lindhe, J. (2005) Ridge alterations following implant placement in fresh extraction sockets: an experimental study in the dog. *Journal of Clinical Periodontology* **32**: 645–652.

Belser, U., Buser, D. & Higginbottom, F. (2004) Consensus statements and recommended clinical procedures regarding esthetics in implant dentistry. *International Journal of Oral and Maxillofacial Implants* **19** (Suppl.): 73–74.

Belser, U., Martin, W., Jung, R., Hämmerle, C.H.F., Schmid, B., Morton, D. & Buser, D. (2007) *ITI Treatment Guide, Volume 1: Implant Therapy in the Esthetic Zone. Single-tooth Replacements*. Berlin: Quintessence Publishing Co. Ltd.

Botticelli, D., Berglundh, T., Buser, D. & Lindhe, J. (2003) The jumping distance revisited: an experimental study in the dog. *Clinical Oral Implants Research* **14**: 35–42.

Botticelli, D., Berglundh, T. & Lindhe, J. (2004a) Hard-tissue alterations following immediate implant placement in extraction sites. *Journal of Clinical Periodontology* **31**: 820–828.

Botticelli, D., Berglundh, T. & Lindhe, J. (2004b) Resolution of bone defects of varying dimension and configuration in the marginal portion of the peri-implant bone. An experimental study in the dog. *Journal of Clinical Periodontology* **31**: 309–317.

Botticelli, D., Persson, L.G., Lindhe, J. & Berglundh, T. (2006) Bone tissue formation adjacent to implants placed in fresh extraction sockets: an experimental study in dogs. *Clinical Oral Implants Research* **17**: 351–358.

Cardaropoli, G., Araújo, M., Hayacibara, R., Sukekava, F. & Lindhe, J. (2005) Healing of extraction sockets and surgically produced – augmented and non-augmented – defects in the alveolar ridge. An experimental study in the dog. *Journal of Clinical Periodontology* **32**: 435–440.

Chen, S.T., Darby, I.B. & Reynolds, E.C. (2007) A prospective clinical study of non-submerged immediate implants: clinical outcomes and esthetic results. *Clinical Oral Implants Research* **18**: 552–562.

Covani, U., Bortolaia, C., Barone, A. & Sbordone, L. (2004) Bucco-lingual crestal bone changes after immediate and delayed implant placement. *Journal of Periodontology* **75**: 1605–1612.

Denissen, H.W. & Kalk, W. (1991) Preventive implantations. *International Dental Journal* **41**: 17–24.

Denissen, H.W., Kalk, W., Veldhuis, H.A. & van Waas, M.A. (1993) Anatomic consideration for preventive implantation. *International Journal of Oral and Maxillofacial Implants* **8**: 191–196.

Ferrus, J., Cecchinato, D., Pjetursson, B.E., Lang, N.P., Sanz, M. & Lindhe J. (2009) Factors influencing ridge alterations following immediate implant placement into extraction sockets. *Clinical Oral Implants Research*, doi: 10.1111/j.1600-0501.2009.01825.x [epub ahead of print].

Hämmerle, C.H., Chen, S.T. & Wilson, T.G. Jr. (2004) Consensus statements and recommended clinical procedures regarding the placement of implants in extraction sockets. *International Journal of Oral and Maxillofacial Implants* **19** (Suppl.): 26–28.

Iasella, J.M., Greenwell, H., Miller, R.L., Hill, M., Drisko, C., Bohra, A.A. & Scheetz, J.P. (2003) Ridge preservation with freeze-dried bone allograft and a collagen membrane compared to extraction alone for implant site development: a clinical and histologic study in humans. *Journal of Periodontology* **74**: 990–999.

Karoussis, I.K., Salvi, G.E., Heitz-Mayfield, L.J., Bragger, U., Hammerle, C.H. & Lang, N.P. (2003) Long-term implant prognosis in patients with and without a history of chronic periodontitis: a 10-year prospective cohort study of the ITI dental implant system. *Clinical Oral Implants Research* **14**: 329–339.

Oates, T.W., West, J., Jones, J., Kaiser, D. & Cochran, D.L. (2002) Long-term changes in soft tissue height on the facial surface of dental implants. *Implant Dentistry* **11**: 272–279.

Paolantonio, M., Dolci, M., Scarano, A., d'Archivio, D., di Placido, G., Tumini, V. & Piattelli, A. (2001) Immediate implantation in fresh extraction sockets. A controlled clinical and histological study in man. *Journal of Periodontology* **72**: 1560–1571.

Pietrokovski, J. (1975) The bony residual ridge in man. *Journal of Prosthetic Dentistry* **34**: 456–462.

Qahash, M., Susin, C., Polimeni, G., Hall, J. & Wikesjo, U.M. (2008) Bone healing dynamics at buccal peri-implant sites. *Clinical Oral Implants Research* **19**: 166–172.

Romeo, E., Lops, D., Amorfini, L., Chiapasco, M., Ghisolfi, M. & Vogel, G. (2006) Clinical and radiographic evaluation of small-diameter (3.3-mm) implants followed for 1–7 years: a longitudinal study. *Clinical Oral Implants Research* **17**: 139–148.

Romeo, E., Lops, D., Margutti, E., Ghisolfi, M., Chiapasco, M. & Vogel, G. (2004) Long-term survival and success of oral implants in the treatment of full and partial arches: a 7-year prospective study with the ITI dental implant system. *International Journal of Oral and Maxillofacial Implants* **19**: 247–259.

Sanz, M., Cecchinato, D., Ferrus, J., Pjetursson, B.E., Lang, N.P. & Lindhe J. (2009) A prospective, randomized, controlled clinical trial to evaluate bone preservation using implants with different geometry placed into extraction sockets in the maxilla. *Clinical Oral Implants Research*, doi: 10.1111/j.1600-0501.2009.01824.x [epub ahead of print].

Schropp, L., Wenzel, A., Kostopoulos, L. & Karring, T. (2003) Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. *International Journal of Periodontics and Restorative Dentistry* **23**: 313–323.

Sclar, A.G. (1999) Preserving alveolar ridge anatomy following tooth removal in conjunction with immediate implant placement. The biocol technique. *Atlas of the Oral and Maxillofacial Surgery Clinics of North America* **7**: 39–59.

Simon, B.I., Von Hagen, S., Deasy, M.J., Faldu, M. & Resnansky, D. (2000) Changes in alveolar bone height and width following ridge augmentation using bone graft and membranes. *Journal of Periodontology* **71**: 1774–1791.

Spray, J.R., Black, C.G., Morris, H.F. & Ochi, S. (2000) The influence of bone thickness on facial marginal bone response: stage 1 placement through stage 2 uncovering. *Annals of Periodontology* **5**: 119–128.

Tomasi, C., Sanz, M., Cecchinato, D., Pjetursson, B.E., Ferrus, J., Lang, N.P. & Lindhe J. (2009) Bone dimensional variations at implants placed in fresh extraction sockets: a multilevel multivariate analysis. *Clinical Oral Implants Research*, doi: 10.1111/j.1600-0501.2009.01848.x [epub ahead of print].

Wennström, J.L., Ekestubbe, A., Grøndahl, K., Karlsson, S. & Lindhe, J. (2004) Oral rehabilitation with implant-supported fixed partial dentures in periodontitis-susceptible subjects. A 5-year prospective study. *Journal of Clinical Periodontology* **31**: 713–724.

Wennström, J.L., Ekestubbe, A., Grøndahl, K., Karlsson, S. & Lindhe, J. (2005) Implant-supported single-tooth restorations: a 5-year prospective study. *Journal of Clinical Periodontology* **32**: 567–574.

Wilson, T.G. Jr., Schenk, R., Buser, D. & Cochran, D. (1998) Implants placed in immediate extraction sites: a report of histologic and histometric analyses of human biopsies. *International Journal of Oral and Maxillofacial Implants* **13**: 333–341.