

Review Article

# Alveolar bone dimensional changes of post-extraction sockets in humans: a systematic review

Fridus Van der Weijden<sup>1,2</sup>,  
Federico Dell'Acqua<sup>3</sup> and Dagmar  
Else Slot<sup>1</sup>

<sup>1</sup>Department of Periodontology, Academic Centre for Dentistry Amsterdam (ACTA), University of Amsterdam and VU University Amsterdam, Amsterdam, The Netherlands; <sup>2</sup>Clinic for Periodontology, Utrecht, The Netherlands; <sup>3</sup>Department of Dental Implants, Università degli Studi di Verona, Verona, Italy

Van der Weijden F, Dell'Acqua F, Slot DE. Alveolar bone dimensional changes of post-extraction sockets in humans :a systematic review. *J Clin Periodontol* 2009; 36: 1048–1058. doi: 10.1111/j.1600-051X.2009.01482.x.

## Abstract

**Objective:** To review the literature to assess the amount of change in height and width of the residual ridge after tooth extraction.

**Material and Methods:** MEDLINE-PubMed and the Cochrane Central register of controlled trials (CENTRAL) were searched through up to March 2009. Appropriate studies which data reported concerning the dimensional changes in alveolar height and width after tooth extraction were included. Approximal height change, mid-buccal change, mid-crestal change, mid-lingual change, Alveolar width change and socket fill were selected as outcome variables. Mean values and if available standard deviations were extracted. Weighted mean changes were calculated.

**Results:** Independent screening of the titles and abstracts of 1244 MEDLINE-PubMed and 106 Cochrane papers resulted in 12 publications that met the eligibility criteria. The reduction in width of the alveolar ridges was 3.87 mm. The mean clinical mid-buccal height loss was 1.67 mm. The mean crestal height change as assessed on the radiographs was 1.53 mm. Socket fill in height as measured relative to the original socket floor was on an average 2.57 mm.

**Conclusion:** During the post-extraction healing period, the weighted mean changes as based on the data derived from the individual selected studies show the clinical loss in width to be greater than the loss in height, assessed both clinically as well as radiographically.

Key words: bone loss; bone resorption; dimensional height and width changes; post-extraction socket; residual ridge resorption; systematic review; tooth extraction

Accepted for publication 23 August 2009

The alveolar process is a tooth-dependent tissue that develops in conjunction with the eruption of the teeth. The tooth is anchored to the jaws via the bundle bone into which the periodontal ligament fibres invest. The volume as well as the shape of the alveolar process is determined by the form of the teeth, their axis of eruption and eventual incli-

nation (Schroeder 1986). Subsequent to the removal of teeth, the alveolar process will undergo atrophy (e.g. Atwood 1957, Hedegård 1962, Tallgren 1972). The bundle bone at the site obviously will lose its function and disappear (Botticelli et al. 2004, Araújo & Lindhe 2005, Araújo et al. 2008).

Tooth extraction is one of the most common dental procedures. Generally, the extraction socket heals uneventfully. However, even with uneventful healing, the alveolar defect that results as a consequence of tooth removal will only become partially restored. Concurrent with bone growth into the socket,

there is also well-documented, resorption of the alveolar ridges. The greatest amount of bone loss is in the horizontal dimension and occurs mainly on the facial aspect of the ridge. There is also loss of vertical ridge height, which has been described to be most pronounced on the buccal aspect (Lekovic et al. 1997, 1998, Araújo & Lindhe 2005). This resorption process results in a narrower and shorter ridge (Pinho et al. 2006) and the effect of this resorptive pattern is the relocation of the ridge to a more palatal/lingual position. The defect resulting from the loss of a tooth may be complicated by previous bone loss due

## Conflict of interest and sources of funding statement

The authors report no conflict of interest related to this study.  
The study was self-funded.

to periodontal disease, endodontic lesions, or a traumatic episode. The situation becomes even more compromised when the alveolus has lost walls or height (Iasella et al. 2003). Loss of alveolar bone may have occurred before tooth extraction because of periodontal disease, periapical pathology, or trauma to teeth and bone. The size of the residual ridge is reduced most rapidly in the first 6 months, but bone resorption activity in the residual ridge continues throughout life at a slower rate resulting in the removal of large amounts of jaw structure (Jahangiri et al. 1998). Morphologic changes in extraction sockets have been described by cephalometric measurements, study cast measurement, radiographic analysis and direct measurements of the ridge following surgical re-entry procedures (Chen et al. 2004).

Except in the most dramatic cases, this ridge collapse following tooth extraction has not been a concern to most dentists or surgical specialist. Damage of the bone tissue during tooth removal may also result in bone loss (Schropp et al. 2003). However, within the past decade, as aesthetics have received more emphasis with treatment planning, resorption of the alveolar ridge following tooth extraction, especially in the anterior region has become a significant problem (Bartee 2001). After tooth removal, the dental team faces the challenge of creating a prosthetic restoration that blends with the adjacent natural dentition.

Sufficient alveolar bone volume and favourable architecture of the alveolar ridge are essential to obtain optimal functional and aesthetic prosthetic reconstructions. Therefore, knowledge about the healing process at extraction sites, including contour changes caused by bone resorption, is essential for treatment planning. It is the purpose of the present paper to describe – based on a systematic search of the available literature – anatomical changes of the residual ridge following tooth extraction. Attention is focused on bone dimensional changes of height and width, as evaluated by clinical or radiographic means.

## Material and Methods

### Focused question

What are the dimensional changes of height and width of the alveolar bone following tooth extraction?

### Search strategy

Two internet sources were selected in the search for papers satisfying the study purpose: The National Library of Medicine, Washington, DC (MEDLINE-PubMed) (1965 up to March 2009) and the Cochrane Central register of controlled trials (CENTRAL) (up to March 2009). All reference lists of the selected studies were screened for additional papers that could meet the eligibility criteria of the study. The databases were searched using the following search term:

### PubMed & Cochrane CENTRAL search

#### Intervention:

<[MeSH terms/all subheadings] “Tooth Extraction” >

OR

<[text words] Tooth Extraction OR Dental Extraction OR Tooth Removal OR Tooth Pulling >

OR

<[text words] Tooth AND Extraction >

AND

#### Outcome:

<[MeSH terms/all subheadings] “Bone Resorption” OR “Alveolar Bone Loss” >

OR

<[text words] Bone Defect OR Bone Resorption OR Alveolar Bone Loss >

This search strategy attempted to be inclusive for any study that evaluated the effect of diverse varieties of post extraction healing. In various trials, the undisturbed healing group (frequently the control group) served to provide data with regard to healing following extraction, thus being randomly collected.

#### The eligibility criteria were:

- randomized-controlled clinical trials, or,
- controlled clinical trials, or,
- prospective clinical studies, or,
- case series,
- conducted in human subjects  $\geq 18$  years,
- subjects in good general health (no systemic disorders),
- intervention: tooth extraction.
- outcome parameters: clinical and/or radiographic alveolar bone dimensions (height and/or width)

Only papers written in English language were included. Letters and narrative or historical reviews were not included in the search. Papers without

abstracts but with titles related to the objectives of this review were selected so that the full text could be screened for eligibility.

### Screening and selection

The papers were screened independently by two reviewers (F. D. A. and G. A. W.), first by title and abstract. Then, as a second step, full-text papers were selected that fulfilled the eligibility criteria for inclusion according to the study aim. After the search, all reference lists of selected studies were screened for additional papers that might meet the eligibility criteria of the study. Any disagreement between the two reviewers was resolved after an additional discussion.

### Assessment of heterogeneity

Factors that were recorded in order to evaluate the heterogeneity of the primary outcome across studies were as follows:

- Study design.
- Duration of follow-up.
- Number, age, range of subjects.
- Tooth type.
- Reason for extraction.
- Smoking status.
- Intervention.
- Evaluation parameters.
- Evaluation method (radiographical or clinical).

### Quality assessment

Assessment of methodological study quality was performed combining the proposed criteria of the RCT-checklist of the Dutch Cochrane Center (2009), the CONSORT statement (2001) Moher et al. (1999, 2001), MOOSE statement (Stroup et al. 2000), STROBE statement (Von Elm et al. 2007), and Esposito et al. (2001) and Needleman et al. (2000). This combination resulted in the quality criteria as mentioned in Box 1. When random allocation, defined inclusion/exclusion, blinding to patient and examiner, balanced experimental groups, an identical treatment between groups except for intervention and report of follow-up was described, the study was classed as at a low risk of bias. When missing one of these five criteria, the study was classed as having a moderate potential risk of bias. Missing two or more of these criteria resulted in a high

Box 1. Quality assessment of the studies included

| Validity         | Study #   | # I<br>Barone<br>et al.<br>(2008) | # II<br>Brägger<br>et al.<br>(1994) | # III<br>Camargo<br>et al.<br>(2000) | # IV<br>Crespi<br>et al.<br>(2009) | # V<br>Fiorellini<br>et al.<br>(2005) | # VI<br>Kerr<br>et al.<br>(2008) | # VII<br>Iasella<br>et al.<br>(2003) | # VIII<br>Lekovic<br>et al.<br>(1997) | # IX<br>Lekovic<br>et al.<br>(1998) | # X<br>Saldanha<br>et al.<br>(2006) | # XI<br>Schropp<br>et al.<br>(2003)  | # XII<br>Serino<br>et al.<br>(2003) |
|------------------|---|-----------------------------------|-------------------------------------|--------------------------------------|------------------------------------|---------------------------------------|----------------------------------|--------------------------------------|---------------------------------------|-------------------------------------|-------------------------------------|--|-------------------------------------|
| External         | Representative population group                 | Yes                               | Yes                                 | Yes                                  | Yes                                | Yes                                   | Yes                              | Yes                                  | Yes                                   | Yes                                 | Yes                                 | Yes  | Yes                                 |
|                  | Eligibility criteria defined                    | Yes                               | ?                                   | Yes                                  | Yes                                | Yes                                   | ?                                | Yes                                  | ?                                     | ?                                   | Yes                                 | Yes  | Yes                                 |
| Internal         | Random allocation                               | Yes                               | Yes                                 | ?                                    | No                                 | Yes                                   | Yes                              | Yes                                  | ?                                     | Yes                                 | NA                                  | NA   | ?                                   |
|                  | Allocation concealment                          | ?                                 | ?                                   | ?                                    | ?                                  | ?                                     | ?                                | ?                                    | ?                                     | ?                                   | NA                                  | NA   | ?                                   |
|                  | Blinded to the patient                          | ?                                 | Yes                                 | ?                                    | ?                                  | Yes                                   | ?                                | ?                                    | ?                                     | ?                                   | NA                                  | NA   | ?                                   |
|                  | Blinded to the examiner                         | ?                                 | Yes                                 | ?                                    | Yes                                | Yes                                   | Yes                              | Yes                                  | ?                                     | Yes                                 | NA                                  | NA   | ?                                   |
|                  | Blinding during statistical analysis            | ?                                 | ?                                   | ?                                    | ?                                  | ?                                     | ?                                | ?                                    | ?                                     | ?                                   | ?                                   | NA   | ?                                   |
|                  | Reported loss to follow-up                      | Yes                               | Yes                                 | Yes                                  | Yes                                | Yes                                   | Yes                              | Yes                                  | Yes                                   | Yes                                 | ?                                   | Yes  | Yes                                 |
|                  | # (%) of drop-outs                              | 0                                 | 0                                   | 0                                    | 0                                  | 0                                     | 0                                | 0                                    | 3 (30%)                               | 0                                   | ?                                   | 2 (4%)   | 9 (20%)                             |
|                  | Treatment identical, except for intervention    | Yes                               | Yes                                 | Yes                                  | Yes                                | Yes                                   | Yes                              | Yes                                  | Yes                                   | Yes                                 | NA                                  | NA   | Yes                                 |
| Statistical      | Sample size calculation and power               | ?                                 | ?                                   | ?                                    | ?                                  | ?                                     | ?                                | Yes                                  | ?                                     | ?                                   | ?                                   | ?  | ?                                   |
|                  | Point estimates presented for primary outcome   | Yes                               | Yes                                 | Yes                                  | Yes                                | Yes                                   | Yes                              | Yes                                  | Yes                                   | Yes                                 | Yes                                 | Yes  | Yes                                 |
|                  | Measures of variability for the primary outcome | Yes                               | Yes                                 | Yes                                  | Yes                                | Yes                                   | Yes                              | Yes                                  | Yes                                   | Yes                                 | No                                  | Yes  | Yes                                 |
|                  | Intention to treat analysis                     | ?                                 | ?                                   | ?                                    | ?                                  | Yes                                   | ?                                | ?                                    | ?                                     | ?                                   | ?                                   | ?  | ?                                   |
| Clinical aspects | Study design                                    | Parallel                          | Parallel                            | Split-mouth                          | Split-mouth                        | Parallel                              | Split-mouth                      | Parallel                             | Split-mouth                           | Split-mouth                         | Split-mouth                         | Cohort   | Parallel and split mouth            |
|                  | Validated measurement                           | ?                                 | ?                                   | ?                                    | ?                                  | ?                                     | ?                                | ?                                    | ?                                     | ?                                   | ?                                   | ?  | ?                                   |
|                  | Calibration examiner                            | ?                                 | ?                                   | ?                                    | ?                                  | ?                                     | ?                                | ?                                    | ?                                     | ?                                   | ?                                   | ?  | ?                                   |
|                  | Reproducibility data shown                      | No                                | No                                  | No                                   | No                                 | Yes                                   | No                               | No                                   | No                                    | No                                  | No                                  | Yes  | No                                  |
|                  | Reason for extraction                           | Requiring extraction              | Scheduled for extraction            | Requiring extraction                 | Requiring extraction               | Requiring extraction                  | Requiring extraction             | Requiring extraction                 | Requiring extraction                  | Requiring extraction                | Requiring extraction                | Root fractures, periodontal problems, endodontic failures, advanced caries | Compromised teeth                   |
|                  | Estimated potential risk of bias                | Moderate                          | Low                                 | High                                 | Moderate                           | Low                                   | Low                              | Low                                  | High                                  | Low                                 | Moderate                            | Low  | High                                |
|                  | Level of evidence                               | IB-                               | IB-                                 | IB-                                  | IB-                                | IB                                    | IB-                              | IB-                                  | 2B                                    | 1B-                                 | 2B                                  | 2B   | 2B                                  |
|                  | CEBM  |                                   |                                     |                                      |                                    |                                       |                                  |                                      |                                       |                                     |                                     |  |                                     |

NA, not applicable; CEBM, Centre for Evidence Based Medicine.

potential risk of bias. In addition, the Centre for Evidence Based Medicine (CEBM) document for "Levels of Evidence" (2009) was used to assess the methodological quality.

#### Data extraction

From the selection of papers that met the criteria, data were processed for analysis. Mean values and standard deviations were extracted by the three reviewers (D. E. S., F. D. A., G. A. W.) with regard to dimensional changes of height and width on the alveolar bone after tooth extraction reported from clinical or radiographical evaluations. Approximal height change, mid-buccal change, mid-crestal change, mid-lingual change, alveolar width change and socket fill were selected as outcome variables.

#### Data analysis

A weighted mean change and standard deviations of the weighted mean change for each outcome variable were calculated using the SPSS Inc. (Chicago, IL, USA) statistical package. If necessary and possible, data for the outcome variables as presented in Tables 3 and 4 were calculated by the authors based on the data as provided by the individual selected studies. Some of the papers provided standard errors (SE) of the mean. The SDs were calculated based on the sample size ( $SE = SD/\sqrt{N}$ ). Ninety-five percent confidence intervals were calculated based on the  $SE \times 1.96$  (as upper bound) and  $SE \times -1.96$  (as lower bound).

## Results

#### Search results

The PubMed search resulted in 1244 papers. The Cochrane search resulted in 106 papers, which provided 36 additional papers to the PubMed search (Table 1). The screening resulted in 42 full-text articles. After full reading, 31 studies were excluded because these did not report on bone dimensional changes. The remaining 11 papers that fulfilled the selection criteria were processed for data extraction. One additional paper (# XI) from the reference list of study # X was included and processed for data extraction

Table 1. Search results

| Selection                           | PubMed | Cochrane | Identical |
|-------------------------------------|--------|----------|-----------|
| Search                              | 1244   | 106      | 70        |
| Titles and abstracts                |        | 1280     |           |
| Excluded by title and abstract      |        | 1238     |           |
| All selected for full-text reading  |        | 42       |           |
| Excluded after full reading         |        | 31       |           |
| Included after full reading         |        | 11       |           |
| Included from reference list        |        | 1        |           |
| Final selection for data extraction |        | 12       |           |

#### Assessment of heterogeneity

After a preliminary evaluation of the selected papers, considerable heterogeneity was observed. Information regarding the study characteristics is presented in Table 2.

#### Study design and duration of follow-up

Of the selected studies, six were randomized-controlled clinical trials (# I–VII) and four studies were controlled clinical trials (# III, IX, X, XII). One study (# VIII) was a case-series and study # XI was a prospective clinical trial. Studies # III, IV, VI, VIII and IX had a split-mouth design. The evaluation period varied between the studies from 3 to 12 months.

#### Subjects, age, tooth types, reason for extraction, smoking status

The studies included between 7 and 46 subjects. Only study # V did not report the age of the participants. Nine out of twelve studies involved regular patient whereas study # II, IX and XII involved patients treated for periodontal disease. Most studies evaluated the effect of tooth extraction at anterior and premolar sites. Three studies also included molars (# IV, VI, XI). Most papers did not describe the reasons for extraction. Two studies extracted compromised teeth such as root fractures, periodontal problems, endodontic failures and advanced caries (XI, XII). Seven studies did not report about the smoking status of the participants. Two studies (# IV, VI) particularly excluded smokers whereas study # I included three smokers out of the 20 subjects monitored. Study # X purposely compared the results following extraction in smokers and non-smokers.

#### Intervention

Most of the extracted data concerned control groups/teeth in studies that evaluated the effect of different therapies on

the post-extraction outcome. The exceptions are studies # II and # X that compared two groups both of which are included in this review. Study # II evaluated the effect of rinsing with chlorhexidine during 1 month following extraction and # X evaluated smoking status in relation to healing. Study # XI evaluated only one group prospectively during a 12-month interval. Studies # II, IV, VI, and XI allowed spontaneous healing following extraction. In the other studies, flaps were raised. Studies # III, VII, X and XII did not attempt to close the extraction wound while in studies # I, V, VIII and IX flaps were raised and eventually sutured and secured to completely close the extraction socket.

#### Evaluation parameters

Studies # I, VII, XI and XII assessed the bone change at the mesial and distal aspect of the extraction site. For the purpose of this review, an average approximal height change was calculated. Studies # I, VI and VII measured the change at the mid-buccal and mid-lingual aspect of the extraction site whereas studies # III, VIII, IX and XII only assessed the mid-buccal aspect. In the radiographical studies, the crestal height change was measured relative to the most coronal aspect of the ridge. Only three studies (# III, VIII, IX) assessed socket fill. Five out of the six clinical studies assessed change in width (# I, III, VII, VIII, IX) while only two out of the six radiographic studies measured alveolar width change (# VI, X).

#### Evaluation method

Studies # II, IV, V, VI, X and XI performed a radiographical evaluation of the alveolar bone in the socket site. Study # II, IV, and XI compared two peri-apical intra-oral radiographs. Bite blocks were used for standardization. Study # X used linear tomography and

Table 2. Overview of the studies processed for data extraction

| ID#   | Author                   | Title  | Design and follow-up time  | Mean age in years (SD) and gender        | Group(s)   | Measures  | Random | Flap raised       |
|-------|--------------------------|--|--|--|--|---|--------|-------------------|
| # I   | Barone et al. (2008)     | Xenograft <i>versus</i> extraction alone for ridge preservation after tooth removal: a clinical and histomorphometric study  | RCT<br>7 months  | > 18<br>(range 26–69)<br>?               | Control:<br>antibiotics for 4 days,<br>chlorhexidine for 21 days<br>and anti-inflammatory drugs<br>for 3 days                          | <i>Clinical</i><br>Reference: acrylic stent<br>Height buccally<br>Height lingually<br>Width<br>Height mesial and distal<br><i>Radiographs</i><br>On standardized radiographs<br>using acrylic bite blocks<br>Parameters: crestal alveolar<br>bone mesial and distal to<br>extraction site | Yes    | Yes closure       |
| # II  | Brägger et al. (1994)    | Effect of chlorhexidine (0.12%) rinses on periodontal tissue healing after tooth extraction  | RCT<br>6 months  | ?<br>?                                   | Control:<br>placebo rinse for 30 days<br>Test: chlorhexidine rinse for<br>30 days<br>Start of rinsing 2 days after<br>tooth extraction | <i>Clinical</i><br>Reference: titanium pins<br>External vertical measure<br>Internal vertical measure<br>Horizontal measure<br><i>Radiographs</i><br>Reference: occlusal stent<br>vertical ridge height   | Yes    | No                |
| # III | Camargo et al. (2000)    | Influence of bioactive glass on changes in alveolar process dimensions after exodontia   | Clinical trial<br>split-mouth<br>6 months  | 44.0 (15.9)<br>8 ♀/8 ♂                   | Control:<br>antibiotics for 7 days<br>chlorhexidine for 21 days<br>and analgesics as needed  | <i>Clinical</i><br>Reference: titanium pins<br>External vertical measure<br>Internal vertical measure<br>Horizontal measure<br><i>Radiographs</i><br>Reference: occlusal stent<br>vertical ridge height   | ?      | Yes<br>No closure |
| # IV  | Crespi et al. (2009)     | Magnesium-Enriched hydroxyapatite compared with calcium sulfate in the healing of human extraction sockets: radiographic and histomorphometric evaluation at 3 months                | RCT<br>split-mouth<br>3 months   | 51.3<br>(range 28–72)<br>7 ♀/8 ♂         | Control:<br>antibiotics for 1 week   | <i>Radiographs</i><br>Reference: occlusal stent<br>vertical ridge height  | Yes    | No                |
| # V   | Fiorellini et al. (2005) | Randomized study evaluating recombinant human bone morphogenetic protein-2 for extraction socket augmentation  | Multi-centre placebo-controlled-randomized clinical trial,<br>4 months<br>RCT<br>split-mouth<br>3 months | ?<br>?                                   | Control:<br>antibiotics for 7–10 days<br>chlorhexidine for? days   | <i>Radiographs</i> (CT scan)<br>Reference: ?<br>alveolar height   | Yes    | Yes<br>Closure    |
| # VI  | Kerr et al. (2008)       | The effect of ultrasound on bone dimensional changes following extraction: a pilot study   | RCT<br>split-mouth<br>3 months   | 53.3<br>(range 36–72)<br>14♀/10 ♂        | Control:<br>spontaneous healing  | <i>Cone beam volumetric tomography</i><br>Reference: metallic plate<br>Height buccal<br>Height lingual<br>Width at crest  | Yes    | No                |
| # VII | Iasella et al. (2003)    | Ridge preservation with freeze-dried bone allograft and a collagen membrane compared with extraction alone for implant side development: a clinical and histological study in humans | RCT<br>6 months  | 51.5 (13.6)<br>(range 28–76)<br>14♀/10 ♂ | Control:<br>antibiotics for 2 weeks<br>chlorhexidine for? days and<br>analgesics for 1 week  | <i>Clinical</i><br>Reference: acrylic stent<br>Horizontal ridge width<br>Vertical ridge height at mid-buccal, mid-lingual, mesial, distal points  | Yes    | Yes<br>No closure |

|        |                        |   |                                      |                                  |   |  |     |                   |
|--------|------------------------|---|--------------------------------------|----------------------------------|---|--|-----|-------------------|
| # VIII | Lekovic et al. (1997)  | A bone regenerative approach to alveolar ridge maintenance following tooth extraction. Report of 10 cases   | Case series split-mouth 6 months     | 49.8<br>6 ♀/4 ♂                  | Control: antibiotics for 7 days, chlorhexidine for ? days and analgesics as needed  | Clinical Reference: titanium pins External vertical measure Internal vertical measure Horizontal measure   | ?   | Yes<br>Closure    |
| # IX   | Lekovic et al. (1998)  | Preservation of alveolar bone on extraction sockets using bioabsorbable membranes   | Clinical trial split-mouth 6 months  | 52.6 (11.8)<br>6 ♀/10 ♂          | Control: antibiotics for 7 days, Chlorhexidine for 15 days and analgesics as needed   | Clinical Reference: titanium pins External vertical measure Internal vertical measure Horizontal measure   | Yes | Yes<br>Closure    |
| # X    | Saldanha et al. (2006) | Smoking may affect the alveolar process dimensions and radiographic bone density in maxillary extraction sites: a prospective study in humans           | Clinical study 6 months              | ?<br>(range 22–67)<br>9 ♀/12 ♂   | Test: smokers (at least 20 cigarettes per day for at least 5 years)<br>Control: non-smokers<br>Chlorhexidine for 1 month and analgesics as needed | Radiographs Reference: acrylic stent with metal sphere<br>On linear tomogram Parameters: alveolar process height and alveolar process width at crest | ?   | Yes<br>No closure |
| # XI   | Schropp et al. (2003)  | Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study                  | Prospective clinical trial 12 months | 45<br>(range 20–73)<br>31 ♀/15 ♂ | Test: spontaneous healing   | Radiographs Reference: ?<br>height at mesial and distal of neighbouring tooth<br>height buccally;<br>height orally;<br>width                         | □   | No                |
| # XII  | Serino et al. (2003)   | Ridge preservation following tooth extraction using a polylactide and polyglycolide sponge as space filler: a clinical and histological study in humans | Clinical trial 6 months              | ?<br>(range 35–64)<br>31 ♀/14 ♂  | Control: chlorhexidine for 2 weeks and analgesics as needed   | Clinical Reference: acrylic stent<br>Alveolar process height between three landmarks:<br>-mesio-buccal;<br>-mid-buccal;<br>-disto-buccal             | ?   | Yes<br>No closure |

an acrylic stent with a fixed reference point (metal sphere). Study # V used computer tomography (CT) scans. These scans were examined by three independent reviewers. However, no reference guide was used. Study # VI used cone beam volumetric tomography scans (CBTV) with a metallic reference plate. Studies # I, III, VII, VIII, IX and XII performed clinical assessments of the healing processes following extraction. Studies # I, VII and XII used a stent guide for the measurements whereas studies # II, VIII and IX placed titanium pins immediately following extraction, which then served as reference points.

### Assessment of quality

Quality assessment is presented in Box 1. The estimated risk of bias is considered to be low for six studies, for three moderate and for three high. Study # V is considered to have the highest level of evidence with an estimated low risk of bias and a score 1B (CEBM 2009). Seven studies receive a score 1B – as they lacked confidence intervals. Two studies had a drop-out rate of >20% and were given score 2B (# VIII, XII). Two were cohort studies with a 2B score (# IX, X).

### Loss to follow-up

From study # XII in total, nine of the original 45 subjects dropped out of the study for reasons unrelated to the treatment provided. However, the paper did not provide information how many of these nine subjects belonged to the control group. In study # VIII at the 3-month re-evaluation visit, three out of the 10 subjects presented with exposed membranes (test teeth). Therefore, these subjects were prematurely exited from this split-mouth study, which had an effect on the number of control sites in the study. From study # XI, two patients withdrew after the 6-month visit and were therefore not included in the 12-month evaluation. The assessments in study # VI involved the measurement of the ridge relative to a reference plate. At the most coronal level, only the lingual ridge provided data for all 12 sites whereas the buccal ridge at this coronal level was absent in six out of the 12 sites.

### Study outcome

The study outcomes are presented in Tables 3 and 4. The clinical data involved anterior and pre-molar sites. The weighted mean changes at the approximal aspect of the neighbouring teeth show a mean loss of 0.64 mm ( $N = 45$ ) (95% CI  $-0.699 < > -0.585$ ). The mid-buccal change was 1.67 mm (95% CI  $-1.910 < > -1.428$ ); including all extracted data ( $N = 84$ ). The loss at the mid-lingual aspect was 2.03 mm ( $N = 32$ ) (95% CI  $-2.486 < > -1.564$ ). For a proper comparison also a weighted mean for the mid-buccal loss was also, calculated using the data as extracted from the same studies (SD = I, VII) that provided mid-lingual data, which showed a mean loss of 2.59 (1.85) mm ( $N = 32$ ). Socket fill in height as measured relative to the original socket floor was on average 2.57 mm (95% CI  $2.446 < > 2.707$ ). The reduction in width of the alveolar ridges was 3.87 mm.

This clinically observed change in width is much larger than what is observed on the radiographs, which is 1.21 mm. However, these data were extracted from different studies and the radiographical data involved apart from the anterior and pre-molar teeth also from the molar teeth. The mean crestal height change as assessed on the radiographs (Table 4) is 1.53 mm ( $N = 111$ ) (95% CI  $-1.696 < > -1.364$ ), which is in line with the clinical observation at the mid-buccal aspect ( $N = 84$ ) being 1.67 mm (Table 3).

The approximal bone height change was on average 0.7 mm being similar to what was clinically assessed. One of the studies included (# II) particularly assessed the effect of a post-extraction therapy of 30 days rinsing with chlorhexidine mouth rinse and showed that this significantly reduced approximal bone loss.

### Discussion

The results from this review with respect to socket fill are presented in Table 3. It shows that on average approximately 2.57 mm of fill in bone height may be expected. The crestal height changes as based on radiographic measurements is approximately 1.59 mm, which can be subdivided based on the clinical assessment as loss on the buccal aspect (1.67 mm) and the lingual aspect (2.03 mm). These data do not support the results as reported by Araújo &

Lindhe (2005). These authors concluded that as the crest of the buccal bone wall in their dog model was comprised solely of bundle bone, the modelling resulted in substantial vertical reduction of the buccal crest (Araújo & Lindhe 2005). The average difference between buccal and lingual crest in their dog model experiment was approximately 2 mm. Even if in the present review for the weighted mean changes (Table 3), the outcome of the same studies ( $N = 32$ ) was used, comparing the buccal and lingual changes, the reduction would be 2.59 ( $\pm 1.85$ ) and 2.03 ( $\pm 1.78$ ), respectively. Although this difference (0.56 mm) is being more pronounced on the buccal aspect, it is still not as prominent as reported by Araújo & Lindhe (2005).

A study conducted by Nevins et al. (2006) determined the fate of a thin buccal bone plate at the prominent roots of maxillary anterior teeth following extractions. Using CT scans, they assessed the height of the crest where the width was 6 mm. Using this parameter, they observed a reduction in height (relative to the 6 mm width) of 5.24 mm. The illustration provided with this paper demonstrated that this was mainly the result of resorption of the buccal wall. These data are in support of the dog model data (Araújo & Lindhe 2005). However, the observed clinical weighted mean changes as calculated in the present review do not substantiate this finding (Table 3). Moreover, the current clinical data are supported by the CBVT scan data (Table 4) as presented in study # VI, where the buccal and lingual changes were more or less comparable. The most likely explanation is that the buccal plate in humans is on average equally prone to resorption as the lingual aspect of the ridge. Both showed a reduction of approximately 2 mm following extraction.

This study does not provide data on soft tissue loss that is an additive with hard tissue loss, and the combined effect of both tissues on total ridge width must be considered. The cohesive relationship between the gingiva and its underlying osseous tissue support has significance in the aesthetic zone.

### Heterogeneity

Data were pooled in a meta-analysis calculating a WMD. Although the meta-analysis is now well established as a method of reviewing evidence, one

common problem is the sources of heterogeneity, in particular clinical differences between studies included. Heterogeneity was investigated to increase the clinical relevance of the conclusions drawn (Thompson 1994). It was attempted to explore some of the possible causes of heterogeneity that could be related to the quality of trial design, accuracy of the outcome measures, population and length of the follow-up. Considerable clinical heterogeneity was observed among the selected studies (Table 3), which shows that the studies are not all estimating the same quantity. This does not necessarily suggest that the true intervention effect varies. The heterogeneity of the data reflects different behaviours of the study populations, differences in study designs and all other factors that may influence the outcomes. Heterogeneity may also be caused by publication bias. Last but not the least, heterogeneity may also be due to chance. In case of considerable heterogeneity, the WMD value should be interpreted with caution. The reader should not quote the WMD as the exact measure for the effect (Higgins & Green 2008). On the other hand, the heterogeneity observed most likely reflects what the dentist encounters in his/her practice population. Not one patient is or behaves the same. The results presented in this review give guidance in what may be clinically expected following tooth extraction. For this purpose, the confidence intervals have also been added that indicate the (im)precision of the study estimates. These provide an indication of how much greater or smaller the true effect is likely to be (Guyat et al. 2008).

### Smoking

Post-extraction wound healing is dependent on molecular and cellular events to occur appropriately. Therefore, it seems logical to assume that the final healing outcome after tooth extraction may be influenced by factors that affect such events (Bartee 2001). A variety of factors may be of influence such as systemic factors including the patient's general health and habits (e.g. smoking). Local factors include the reasons for extraction, the number and proximity of teeth to be extracted, the condition of the socket before and after tooth extraction, the influence of tissue biotype on healing, local differences between sites in the mouth and the

Table 3. Clinical outcomes in millimetres (standard deviation in parenthesis) and 95% confidence intervals (CI)

| #              | study                 | # of subjects | # of teeth and type | Clinical outcomes (in mm)                                  |  |                           |  |                            |  |
|----------------|-----------------------|---------------|---------------------|--|--|---------------------------|--|----------------------------|--|
|                |                       |               |                     | aproximal height change °                                  | mid-buccal change                        | mid-lingual change        | alveolar width change                    | socket fill                |  |
| # I            | Barone et al. (2008)  | 20            | 20 A/P              | Mesial: -0.4(1.2)<br>Distal: -0.5 (1.0)<br>Average: -0.45▲ | -3.6 (1.5)                               | -3.0 (1.6)                | -4.5 (0.8)                               | □                          |  |
| # III          | Camargo et al. (2000) | 16            | 16 A/P              | □  | -1.00 (9▲)                               | □                         | -3.06 (9.64▲)                            | +3.00▲                     |  |
| # VII          | Iasella et al. (2003) | 12            | 12 A/P              | Mesial: -1.0 (0.8)<br>Distal: -0.8 (0.8)<br>Average: -0.9▲ | -0.90 (1.60)                             | -0.4 (1.0)                | -2.63 (2.29)                             | □                          |  |
| # VIII         | Lekovic et al. (1997) | 10            | 10 A/P              | □  | N = 7*<br>-1.00 (0.00▲)<br>-1.50 (1.04▲) | □                         | N = 7*<br>-4.43 (5.03▲)<br>-4.56 (1.32▲) | N = 7*<br>+1.92▲<br>+2.44▲ |  |
| # IX           | Lekovic et al. (1998) | 16            | 16 A/P              | □  | -1.50 (1.04▲)                            | □                         | -4.56 (1.32▲)                            |                            |  |
| # XII          | Serino et al. (2003)  | 12            | 13 A/P              | Mesial: -0.6 (1.0)<br>Distal: -0.8 (1.5)<br>Average: -0.7▲ | -0.8 (1.6)                               | □                         | □  | □                          |  |
| All $M_w$ (SD) |                       | 64            | A/P                 | -0.64 (0.19)▲<br>(N = 45)                                  | -1.67 (1.11)▲<br>(N = 84)                | -2.03 (1.28)▲<br>(N = 32) | -3.87 (0.82)▲<br>(N = 71)                | +2.57 (0.40)▲<br>(N = 39)  |  |
| 95% CI         |                       |               |                     | -0.699 < > -0.585  | -1.910 < > -1.428                        | -2.486 < > -1.564         | -4.059 < > -3.673                        | 2.446 < > 2.707            |  |

\*Three patients in the test group presented with exposed membranes at the 3-month re-evaluation and were therefore prematurely exited from this split-mouth study.

dental arches and the type of interim prosthesis used (Chen et al. 2004).

The findings of a 6-month prospective study selected for this review suggest that smoking may significantly affect healing after tooth extraction. Thus, Saldanha et al. (2006) showed that smoking may lead to an enhanced dimensional reduction. The precise mechanisms by which tobacco smoke interferes with healing is not understood. Part of the negative influence of smoking has been attributed to nicotine, which is one of the major constituents of the particulate phase of tobacco smoke. It is one of the most cytotoxic and vasoactive substance. Based on observations by Saldanha et al. (2006), one may expect 0.5 mm more bone crest reduction following tooth extraction in smokers than in non-smokers.

**Chlorhexidine**

Another study selected for this review assessed the influence of a 30-day period of chlorhexidine digluconate (CHX) rinse on the healing activity of the periodontal tissues adjacent to an extraction wound (Brägger et al. 1994). The CHX group demonstrated an increase in bone density in the apposition phase between 1 and 6 months. The patients rinsing for 1 month with a placebo solution lost almost 1 mm of bone height over the 6 months following tooth extraction, while in the CHX group, practically no change (0.06 mm) was observed. This is in agreement with a previous report in which the healing of periodontal tissues around teeth located adjacent to an extraction wound were assessed. A tendency for less recession and shallower probing pocket depths were observed in the CHX group (Lang et al. 1994). Studies # I, II, V, VII, VIII, IX, X and XII all provided chlorhexidine rinse for post-extraction healing. Studies # I, III, IV, V, VII, VIII and IX even prescribed antibiotics. These post-extraction therapies may have influenced the study outcomes in a positive manner (Brägger et al. 1994, Bystedt et al. 1997).

**Positive effect**

In some cases, the healing extraction can also be considered to provide a beneficial effect. A reduction in pocket probing depth following tooth extraction in addition to that obtained by scaling and root planing has been demonstrated

Table 4. Radiographical outcomes in millimetres (standard deviation in parenthesis) and 95% confidence intervals (CI)

| #              | study                    | # of subjects                 | # of teeth & type         | Radiographic outcomes (in mm)  |                         |                         |  |   |
|----------------|--------------------------|-------------------------------|---------------------------|--|-------------------------|-------------------------|--|---|
|                |                          |                               |                           | approximal height change ○   | mid-buccal change       | mid-lingual change      | crestal height change                      | alveolar width change                             |
| # II           | Brägger et al. (1994)    | 23<br>test: 11<br>control: 12 | 16<br>16<br>type?         | -0.06 (0.89)<br>-0.93 (0.74)<br>Average: -0.7▲                       | □                       | □                       | □  | □   |
| # IV           | Crespi et al. (2009)     | 15                            | 15<br>P/M                 | □  | □                       | □                       | -3.75 (0.63)                               | □   |
| # V            | Fiorellini et al. (2005) | 20                            | 20<br>A/P                 | □  | □                       | □                       | N = 19<br>-1.17 (1.23)                     | □   |
| # VI           | Kerr et al. (2008)       | 12                            | 12<br>A/P/M               | □  | N = 12<br>-0.95 (1.34▲) | N = 12<br>-1.12 (0.98▲) | Average: -1.04▲<br>SM: -1.5▲<br>NSM: -1.0▲ | N = 6<br>-2.20 (1.99▲)<br>SM: -1.3▲<br>NSM: -0.6▲ |
| # X            | Saldanha et al. (2006)   | 21<br>SM:10<br>NSM: 11        | 10<br>11<br>A (upper jaw) | □  | □                       | □                       | Average: -1.24▲<br>N = 44<br>-1.2          | Average: -0.93▲                                   |
| # XI           | Schropp et al. (2003)    | 46                            | 46<br>P/M                 | N = 44<br>Mesial: -0.9<br>Distal: -0.5<br>Average: -0.7▲<br>(N = 60) | □                       | □                       | -1.53 (0.88)▲<br>(N = 111)                 | -1.21 (0.54)<br>(N = 27)                          |
| All $M_w$ (SD) |                          | 125                           | A/P/M                     | -0.7 (0.0)▲<br>(N = 60)  | □                       | □                       | -1.696 < > -1.364                          | -1.425 < > -0.999                                 |
| 95% CI         |                          |                               |                           | not relevant   |                         |                         |  |   |

Subscript to the Tables 3 and 4:  
 A, incisor/canine; P, pre-molar; M, molar; N, number of teeth extracted; ▲, Calculated by the authors; □, data not provided; ○, crestal alveolar bone height change at teeth adjacent to extraction sites;  $M_w$ , weighted mean; SM = smoker; NSM, non-smoker.

at sites adjacent to an edentulous area. This reduction was the result of gingival shrinkage and was greatest at sites of deep pocket probing depths. The beneficial effects of tooth extraction to adjacent periodontium may be considered when patients with advanced periodontal disease are treated comprehensively (Grassi et al. 1987).

**Surgical intervention**

In studies # I, III, V, VII, VIII, IX, X and XII, buccal flaps were raised before tooth extraction. In some studies, primary closure of the extraction socket was accomplished (# I, V, VIII, IX). This primary closure requires the advancement of a large, full-thickness flap. It is well established in the periodontal literature that the elevation of a full-thickness flap (muco-periosteal flap) may cause loss of attachment and resorption of bone (for a review, see Heitz-Mayfield et al. 2002). The reported crestal bone loss after a full-thickness flap elevation is approximately 0.6 mm (Wood et al. 1972). Flap elevation is believed to compromise the vascular supply of the site, contributing to soft-tissue recession and possibly limiting future regenerative potential (Sclar 1999). The direct contact between gingival connective tissue with the socket area may favour alveolar bone resorption. This additional osteoclastic resorption will occur on the external aspect of the buccal bone plate. Tavtigan (1970) showed a mean loss of 0.47 mm of the facial radicular alveolar crest after full-thickness flap procedures. In recent animal models, additional volumetric shrinkage of 0.5–0.7 mm could be observed (Blanco et al. 2008, Fickl et al. 2008). The data from Araújo and Lindhe (2009) suggest that the difference between the flap and the flapless group may disappear after longer (≥6 months) healing periods.

**Evaluation time**

The studies included in this review had evaluation periods, which varied from 3 to 12 months. Johnson (1969) reported that the process that resulted in tissue reduction seemed to be more pronounced during the initial phase of wound healing than during later periods following tooth removal. Most of the dimensional alterations – horizontal as well as vertical – of the alveolar ridge took place during the first 3 months of

healing (Johnson 1969, Schropp et al. 2003). Therefore, this review provides a summary of data that reflect what can clinically be expected by the practitioner to occur following tooth extraction.

## Conclusion

During the post-extraction healing period, the weighted mean changes as based on the data derived from the individual selected studies show the clinical loss in width (3.87 mm) to be greater than the loss in height, assessed both clinically (1.67–2.03 mm) as well as radiographically (1.53 mm).

## Acknowledgements

The authors thank Prof. Dr. J. Lindhe (department of Periodontology, Institute for Odontology, Göteborg University, Sweden) for his comments and suggestions.

This paper was prepared as a part of the obligation for the first author to fulfil the requirements of the New York University College of Dentistry, Linhart Continuing Dental Education Program, "Current Concepts in American Dentistry, Implantology and Periodontics". The second author joined the department of Periodontology of ACTA as a dental student from the Università degli Studi di Verona, Italy, through the *Erasmus student exchange programme* as part of the *SOCRATES programme for education in Europe*.

## References

- Araújo, M., Linder, E., Wennström, J. & Lindhe, J. (2008) The influence of Bio-Oss collagen on healing of an extraction socket: an experimental study in the dog. *The International Journal of Periodontics and Restorative Dentistry* **28**, 123–135.
- 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. & Lindhe, J. (2009) Ridge alterations following tooth extraction with and without flap elevation: an experimental study in the dog. *Clinical Oral Implants Research* **20**, 545–549.
- Atwood, D. A. (1957) A cephalometric study of the clinical rest position of the mandible. Part II. The variability in the rate of bone loss following the removal of occlusal contacts. *Journal of Prosthetic Dentistry* **7**, 544–552.
- Barone, A., Aldini, N. N., Fini, M., Giardino, R., Calvo Guirado, J. L. & Covani, U. (2008) Xenograft versus extraction alone for ridge preservation after tooth removal: a clinical and histomorphometric study. *Journal of Periodontology* **79**, 1370–1377.
- Bartee, B. K. (2001) Extraction site reconstruction for alveolar ridge preservation. Part 1: rationale and materials selection. *Journal of Oral Implantology* **27**, 187–193.
- Blanco, J., Nunez, V., Aracil, L., Munoz, F. & Ramos, I. (2008) Ridge alterations following immediate implant placement in the dog: flap versus flapless surgery. *Journal of Clinical Periodontology* **35**, 640–648.
- Botticelli, D., Berglundh, T. & Lindhe, J. (2004) Hard-tissue alterations following immediate implant placement in extraction sites. *Journal of Clinical Periodontology* **31**, 820–828.
- Brägger, U., Schild, U. & Lang, N. P. (1994) Effect of chlorhexidine (0.12%) rinses on periodontal tissue healing after tooth extraction. (II). Radiographic parameters. *Journal of Clinical Periodontology* **21**, 422–430.
- Bystedt, H., Dahlbäck, A. & Nord, C. E. (1997) Concentration of azidocillin, erythromycin, doxycycline and clindamycin in dental alveolar serum after single oral doses. *International Journal of Oral Surgery* **6**, 65–74.
- Camargo, P. M., Lekovic, V., Weinlaender, M., Klokkevold, P. R., Kenney, E. B., Dimitrijevic, B., Nedic, M., Jancovic, S. & Orsini, M. (2000) Influence of bioactive glass on changes in alveolar process dimensions after exodontia. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **90**, 581–586.
- Centre for Evidence-based Medicine (CEBM), University of Oxford (England) – Levels of Evidence. (2009). Available at <http://www.cebm.net/index.aspx?o=1025> (accessed 24 August 2009).
- Chen, S. T., Wilson, T. G. Jr. & Hämmerle, C. H. (2004) Immediate or early placement of implants following tooth extraction: review of biologic basis, clinical procedures, and outcomes. *International Journal of Oral and Maxillofacial Implants* **19**, 12–25.
- Consort statement. (2001). Available at <http://www.consort-statement.org/consort-statement/> (accessed 24 August 2009).
- Crespi, R., Capparè, P. & Gherlone, E. (2009) Magnesium-enriched hydroxyapatite compared to calcium sulfate in the healing of human extraction sockets: radiographic and histomorphometric evaluation at 3 months. *Journal of Periodontology* **80**, 210–218.
- Esposito, M., Coulthard, P., Worthington, H. V. & Jokstad, A. (2001) Quality assessment of randomized controlled trials of oral implants. *International Journal of Oral and Maxillofacial Implants* **16**, 783–792.
- Fickl, S., Zuhr, O., Wachtel, H., Bolz, W. & Huerzeler, M. (2008) Tissue alterations after tooth extraction with and without surgical trauma: a volumetric study in the beagle dog. *Journal of Clinical Periodontology* **35**, 356–363.
- Fiorellini, J. P., Howell, T. H., Cochran, D., Malmquist, J., Lilly, L. C., Spagnoli, D., Toljanic, J., Jones, A. & Nevins, M. (2005) Randomized study evaluating recombinant human bone morphogenetic protein-2 for extraction socket augmentation. *Journal of Periodontology* **76**, 605–613.
- Grassi, M., Tellenbach, R. & Lang, N. P. (1987) Periodontal conditions of teeth adjacent to extraction sites. *Journal of Periodontology* **14**, 334–339.
- Guyatt, G., Rennie, D., Meade, M.O. & Cook, D.J. (2008) *User's Guides to the Medical Literature-A Manual for Evidence Based Clinical Practice*. American Medical Association Press, Chicago, USA.
- Hedegård, B. (1962) Some observations on tissue changes with immediate maxillary dentures. *Dental Practitioner* **13**, 70–78.
- Heitz-Mayfield, L. J. A., Trombelli, L., Heitz, F., Needleman, I. G. & Moles, D. R. (2002) A systematic review of the effect of surgical debridement vs. non-surgical debridement for the treatment of chronic periodontitis. *Journal of Clinical Periodontology* **29**, 92–102.
- Higgins, J. P. T. & Green, S. (2008) *Cochrane Handbook for Systematic Reviews of Interventions Version 5.0.0*. The Cochrane Collaboration, 2008. Available at <http://www.cochrane-handbook.org> (accessed 24 August 2009).
- 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.
- Jahangiri, L., Devlin, H., Ting, K. & Nishimura, I. (1998) Current perspectives in residual ridge remodeling and its clinical implications: a review. *Journal of Prosthetic Dentistry* **80**, 224–237.
- Johnson, K. (1969) A study of the dimensional changes occurring in the maxilla following tooth extraction. *Australian Dental Journal* **14**, 241–244.
- Kerr, E. N., Mealey, B. L., Noujeim, M. E., Lasho, D. J., Nummikoski, P. V. & Mellonig, J. T. (2008) The effect of ultrasound on bone dimensional changes following extraction: a pilot study. *Journal of Periodontology* **79**, 283–290.
- Lang, N. P., Schild, U. & Brägger, U. (1994) Effect of chlorhexidine (0.12%) rinses on periodontal tissue healing after tooth extraction. (I). Clinical parameters. *Journal of Periodontology* **79**, 415–421.
- Lekovic, V., Camargo, P. M., Klokkevold, P. R., Weinlaender, M., Kenney, E. B., Dimitrijevic, B. & Nedic, M. (1998) Preservation of alveolar bone in extraction sockets using bioabsorbable membranes. *Journal of Periodontology* **69**, 1044–1049.
- Lekovic, V., Kenney, E. B., Weinlaender, M., Han, T., Klokkevold, P., Nedic, M. & Orsini, M. (1997) A bone regenerative approach to alveolar ridge maintenance following tooth extraction. Report of 10 cases. *Journal of Periodontology* **68**, 563–570.

- Moher, D., Cook, D. J., Eastwood, S., Olkin, I., Rennie, D. & Stroup, D. F. (1999) Improving the quality of reports of meta-analyses of randomised controlled trials: the QUOROM statement. Quality of reporting of meta-analyses. *Lancet* **354**, 1896–1900.
- Moher, D., Schulz, K. F. & Altman, D. G. (2001) The CONSORT statement: revised recommendations for improving the quality of reports of parallel-group randomised trials. *Lancet* **357**, 1191–1194.
- Needleman, I., Moles, D. R. & Worthington, H. (2000) Evidence-based periodontology, systematic reviews and research quality. *Journal of Periodontology* **37**, 12–28.
- Nevins, M., Camelo, M., De Paoli, S., Friedland, B., Schenk, R. K., Parma-Benfenati, S., Simion, M., Tinti, C. & Wagenberg, B. (2006) A study of the fate of the buccal wall of extraction sockets of teeth with prominent roots. *The International Journal of Periodontics and Restorative Dentistry* **26**, 19–29.
- Pinho, M. N., Roriz, V. L., Novaes, A. B. Jr., Taba, M. Jr., Grisi, M. F., de Souza, S. L. & Palioto, D. B. (2006) Titanium membranes in prevention of alveolar collapse after tooth extraction. *Implant Dentistry* **15**, 53–61.
- RCT-Checklist of the Dutch Cochrane Center. (2009). Available at <http://www.cochrane.nl/Files/documents/Checklists/RCT.pdf> (accessed 24 August 2009).
- Saldanha, J. B., Casati, M. Z., Neto, F. H., Sallum, E. A. & Nociti, F. H. Jr. (2006) Smoking may affect the alveolar process dimensions and radiographic bone density in maxillary extraction sites: a prospective study in humans. *Journal of Oral and Maxillofacial Surgery* **64**, 1359–1365.
- Schroeder, H.-E. (1986) The periodontium. In: Oksche, A. & Vollrath, L. (eds). *Handbook of Microscopic Anatomy*, Vol. V/5, pp. 233–246. Berlin: Springer.
- 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. *The International Journal of Periodontics and Restorative Dentistry* **23**, 313–323.
- Sciar, A. G. (1999) Preserving alveolar ridge anatomy following tooth removal in conjunction with immediate implant placement. The Bio-Col technique. *Atlas of the Oral and Maxillofacial Surgery Clinics of North America* **7**, 39–59.
- Serino, G., Biancu, S., Iezzi, G. & Piattelli, A. (2003) Ridge preservation following tooth extraction using a polylactide and polyglycolide sponge as space filler: a clinical and histological study in humans. *Clinical Oral Implants Research* **14**, 651–658.
- Stroup, D. F., Berlin, J. A., Morton, S. C., Olkin, I., Williamson, G. D., Rennie, D., Moher, D., Becker, B. J., Sipe, T. A. & Thacker, S. B. (2000) Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis of Observational Studies in Epidemiology (MOOSE) group. *Journal of the American Medical Association* **283**, 2008–2012.
- Tallgren, A. (1972) The continuing reduction of the residual alveolar ridges in complete denture wearers: a mixed longitudinal study covering 25 years. *Journal of Prosthetic Dentistry* **27**, 120–132.
- Tavtigian, R. (1970) The height of the facial radicular alveolar crest following apically positioned flap operations. *Journal of Periodontology* **41**, 412–418.
- Thompson, S. G. (1994) Why sources of heterogeneity in meta-analysis should be investigated. *British Medical Journal* **309**, 1351–1355.
- von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C. & Vandenbroucke, J. P. (2007) STROBE Initiative. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* **370**, 1453–1457.
- Wood, D. L., Hoag, P. M., Donnenfeld, O. W. & Rosenfeld, L. D. (1972) Alveolar crest reduction following full and partial thickness flaps. *Journal of Periodontology* **43**, 141–144.

## Address:

G.A. van der Weijden  
 Department of Periodontology  
 Academic Centre for Dentistry Amsterdam (ACTA)  
 University of Amsterdam and VU University Amsterdam  
 Louwesweg 1, 1066 EA Amsterdam  
 The Netherlands  
 E-mail: ga.vd.weijden@acta.nl

**Clinical Relevance**

*Scientific rationale for the study:* Loss of teeth is such a frequent condition that it is easy to forget how it will invariably transform the natural configuration of the basal alveolar bone complex. Dependent on the healing pattern this may pose a problem for the clinician. It creates a challenging aesthetic problem in the fabrication of an implant-supported restoration or a conventional prosthesis. Generally, extraction sockets heal uneventfully. However,

even with uneventful healing, the alveolar defect that results as a consequence of tooth removal will only achieve partial bone fill. In order to have an ideal aesthetic outcome, a sufficient ridge volume and a stable soft tissue margin is needed.

*Principal findings:* The weighted mean changes following extraction based on the data derived from the individual studies show clinically a loss in width of 3.87 mm and a loss in height of 1.67–2.03 mm.

*Practical implications:* Understanding about the healing process at extraction sites, including contour changes caused by bone resorption, is essential for treatment planning. Concurrent with bone growth into the socket, there is also well-documented resorption of the alveolar ridge. This knowledge of the amount of hardsoft tissue change following tooth extraction may help clinicians to prevent possible clinical problems in the aesthetics zone.