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Author

Graziani, Filippo, Dent, M Clin, Cei, Silvia, Ivanovski, Saso, La Ferla, Fabio, Gabriele, Mario

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# A Systematic Review of the Effectiveness of Bone Collectors

Filippo Graziani, DDS, M Clin Dent, PhD<sup>1</sup>/Silvia Cei, DDS, PhD<sup>2</sup>/Saso Ivanovski, BDS, MSc, PhD<sup>3</sup>/  
Fabio La Ferla, DDS<sup>2</sup>/Mario Gabriele, MD, DDS<sup>4</sup>

**Purpose:** Bone collectors are used to harvest bone debris for grafting procedures during implant surgery. The particulate bone debris gathered through filtration has been frequently used in minor regenerative surgical procedures. Nevertheless, the biological potency of such grafts is still unclear. The objective of this study was to systematically review the use of bone collectors in implant dentistry, focusing on the quantity, quality, and bacterial contamination of the bone collected. **Materials and Methods:** Following the production of a detailed protocol, screening and quality assessment of the literature were conducted in duplicate and independently. The outcome measures that were assessed were: (1) quantity of collected debris, (2) quality of the collected bone debris, and (3) bacterial contamination. **Results:** There is a limited amount of information on the nature of bone obtained through collectors. Eleven studies satisfied the inclusion criteria. Bone collectors are able to retain a small amount of bone for minor surgical procedures. The presence of vital bone cells has not been demonstrated routinely, while consistent bacterial contamination has been observed. **Discussion:** Bone collected through bone filters appears to be sufficient for small regenerative procedures. Clinicians should bear in mind that presence of bacterial pathogens is always shown with the use of bone collectors. Presurgical chlorhexidine oral rinsing and a strict aspiration protocol must be used to minimize the bacterial contamination of the debris collected. **Conclusions:** Although bone collectors are capable of amassing small amounts of bone, the vitality of this bone could not be consistently demonstrated and the collected debris was always contaminated by bacteria. Therefore, the bone debris amassed in bone collectors is not an ideal grafting material and should be utilized with caution. *INT J ORAL MAXILLOFAC IMPLANTS* 2007;22:729–735

**Key words:** bone collectors, bone traps, dental implants, oral surgery, systematic review

Autogenous bone is considered the gold standard for grafting materials because of its superior osteogenic and osteoinductive properties.<sup>1–4</sup> The choice of an autogenous donor site is often based on the amount of bone needed. Extraoral bone grafts are usually taken from the iliac crest,<sup>5–7</sup> the tibia,<sup>8</sup> or the skull<sup>5</sup> and are used when large amounts of bone

are needed.<sup>9,10</sup> These procedures result in significant morbidity and discomfort for the patient.<sup>6,11</sup> Conversely, when smaller amounts of bone are required, intraoral grafting sources are usually preferred to decrease patient discomfort postoperatively.<sup>12</sup> The use of intraoral sources for grafting has several advantages, including reduced operating time, lower morbidity, reduced hospitalization time, and avoidance of cutaneous scarring.<sup>2,12,13</sup> A second surgical site is still needed. However, the need for a second surgical site can be avoided with the use of bone collectors to obtain bone during the surgical procedure.

Bone collectors, or bone traps, are filters placed in the surgical suction device to collect the bone debris produced during bone drilling for implant site preparation (Fig 1). These devices were first described in the periodontology literature<sup>14,15</sup> and subsequently reported in the otolaryngology literature.<sup>16,17</sup> More recently, collected bone debris has also been used for bone augmentation to correct small peri-implant

<sup>1</sup>Assistant Professor, Department of Surgery, Section of Oral Surgery, University of Pisa, Italy, and Department of Periodontology, Eastman Dental Institute, University College of London, United Kingdom.

<sup>2</sup>Research Fellow, Department of Surgery, Section of Oral Surgery, University of Pisa, Italy.

<sup>3</sup>Professor and Chair of Periodontology, School of Dentistry and Oral Health, Griffith University, Southport, Australia.

<sup>4</sup>Full Professor of Oral Surgery, Department of Surgery, Section of Oral Surgery, University of Pisa, Italy.

**Correspondence to:** Dr Filippo Graziani, Department of Surgery, Section of Oral Surgery, University of Pisa, Via Roma 67, 56100 Pisa, Italy. Fax: +39050555232. E-mail: f.graziani@med.unipi.it



**Fig 1** Debris collected with a bone filter.



**Fig 2** Dehiscence-like bony defect.



**Fig 3** Filtered material grafted in the peri-implant defect.

defects (Figs 2 and 3).<sup>18,19</sup> The use of bone collectors allows acquisition of bone for grafting with no additional discomfort for the patient.<sup>20</sup> However, little evidence exists to provide guidelines for the use of bone collectors in implant dentistry, as few studies have assessed the material that is amassed in these devices.<sup>21–24</sup> Particularly, the ability to retain bone, the quality of the collected debris, and the possibility of bacterial contamination are of critical importance. The rationale of autogenous bone grafts is based on the assumption that sufficient bone debris would be collected and that such debris retains its osteogenic potential and is free of bacterial infection.<sup>4</sup> However, it is not clear whether these properties are preserved following the milling and filtration process.

The aim of this study was to evaluate, through a systematic review of the literature, the biologic rationale supporting the clinical usage of bone collectors in implant dentistry.

## MATERIALS AND METHODS

### Study Selection

To be eligible for inclusion in the review, studies had to examine bone debris collected with the use of bone collectors in *in vivo* models. No language restrictions were applied.

The outcome measures that were assessed were

- ability to retain bone debris
- quality of the collected debris
- bacterial contamination of bone debris collected

### Searching

Searches of the Central Register of Controlled Trials (CENTRAL), PUBMED, and EMBASE were conducted through January 2006 using the search strategy: 'bone trap\$' OR 'bone collect\$'. All the titles and abstracts were analyzed by 2 reviewers (FG, FLF). Hand searching included *International Journal of Oral & Maxillofacial Implants*, *Clinical Oral and Implants Research*, *Journal of Oral and Maxillofacial Surgery*, *International*

*Journal of Oral and Maxillofacial Surgery*, and *British Journal of Oral and Maxillofacial Surgery*. The reference lists of the included articles were reviewed for the presence of other eligible publications. Articles included were later analyzed *in extenso*.

### Validity Assessment of Review Method

The reviewers were calibrated for study screening against the lead reviewer (FG). Each round of calibration consisted of a duplicate, independent validity assessment of 20 titles and abstracts from the search. After 2 rounds of calibration, a consistent level of agreement was found (unweighted K score from first to third exercise: 0.9, 1, 1). Only studies on the use of bone collectors describing at least 1 of the 3 outcome measures were included in the review. Any disagreement was resolved by discussion among reviewers (FG, FLF, MG).

### Data Synthesis

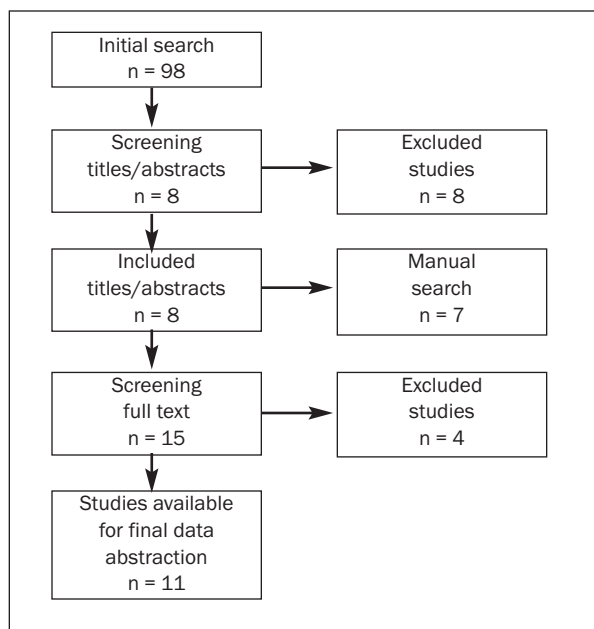
Data were synthesized in evidence tables using mean and range. Decisions on possible meta-analysis were made based on the similarity between the studies.

## RESULTS

The electronic search identified 98 articles (Fig 4). Screening of titles and abstracts led to rejection of 90 articles. The full text of the remaining 8 articles was then obtained (Table 1). Hand searching identified an additional 7 articles for full-text analysis. Four of these articles were later excluded. Therefore, 11 articles met the criteria for inclusion in this systematic review (Table 2). No meta-analysis was performed due to the heterogeneity of the included studies, especially in terms of the use of different bone collectors and a variety of clinical methodologies.

### Characteristics of the Bone Collectors in the Included Studies

Five different types of bone collectors were described in the included literature. These 5 devices

**Table 1** Reasons for Exclusion of Studies

	No. of studies
No. of articles excluded on the basis of their abstracts	90
Humans studies: no usage of bone collectors	41
Animals studies: no usage of bone collectors	49
Excluded full-text articles	4
Clinical studies not assessing inclusion criteria	2
Bone not collected in vivo	2

**Fig 4** Flow of articles during the review.

are commercially available: Osseous Coagulum Trap (OTC Quality Aspirators; Duncanville, TX); Frios bone collector (FBC; Friatec, Mannheim, Germany); IMTEC bone collectors (IM; IMTEC, Ardmore, OK), Knochenfiter KFT2 (KF; Schlumbohm OHG, Brokstedt, Germany), and Fa (FA; Sulzer-Medica, Freiburg, Germany).

### Ability to Retain Bone Debris

Two studies investigated the clinical performance of the bone traps with regard to the amount of bone collected.<sup>20,24</sup> A mean of 0.03 g of bone (range: 0.02 to 0.09 g) was obtained during single implant site preparation with OTC; a mean of 0.05 g (range: 0.00 to 0.08 g) was obtained with FBC.<sup>24</sup> During multiple maxillary implant site drilling, the amount of bone collected was 0.34 g (range: 0.07 to 0.06 g) with OTC and 0.09 g (range: 0.01 to 0.18 g) with FBC. Significant differences were only observed between OTC and FBC with respect to the amount of bone collected following multiple mandibular implant site preparation: 0.14 g (0.07 to 0.28 g) using OTC compared to 0.06 g (0.02 to 0.14 g) using FBC.<sup>24</sup>

Volumetric measurements were performed in only 1 study. Twenty-four implants (4.0 × 13 mm implants) were placed in 9 patients. Bone collectors (IM) were used in each implant surgery. A mean of 0.163 ± 0.070 mL of bone was collected in the mandible, while a mean of 0.196 ± 0.099 mL was collected in the maxilla.<sup>20</sup> No statistical differences were reported between the maxilla and mandible or with respect to patient age or sex.

### Quality of the Collected Debris

Six studies considered the quality of the collected debris utilizing a variety of techniques aimed at assessing its vitality and osteogenic potential.<sup>1,4,20,21,24,25</sup>

Histologic analysis of the debris collected during implant surgery indicated that the material was composed of bone and coagulum.<sup>24</sup> The collected bone showed a well-preserved structure with a large amount of osteocytes in a calcified matrix.<sup>21</sup> The results were not stratified according to the type of device used.

Histomorphometrically, the percentage of bone in the samples collected by FBC ranged from 92% to 100%, whereas in the samples collected by OCT, the percentage of bone ranged from 0% to 85%. Excess coagulum was noticed every time a blockage occurred during surgery (11 times for OCT and 1 time for FBC).<sup>24</sup>

Osteoblast-like cells could be identified in only a portion of the collected samples. Using the FA bone collector, the presence of bone cells was detected in 65% of the total trapped material from human implant sites.<sup>25</sup> In an animal porcine model, cellularity was noticed in only 5 of 10 explants; FBC was used.<sup>1</sup>

Using cortical bone material harvested from pigs, cell outgrowth was 487 ± 413 cells/mg after 14 days.<sup>1</sup> The number of cells seemed to be affected by the type of bur used during drilling; more cells were maintained with the use of diamond ball drills compared to implant burs and ball reamers.<sup>4</sup>

A comparison of the bone material obtained using bone filters with that obtained through chisels or

Table 2 Characteristics of the Included Studies

Study	Type of studies	No. of subjects in test group	Procedure	Collection areas	Bone collector used	Aspiration protocol	Ability to retain bone debris	Quality of the collected debris	Bacterial contamination of bone debris collected
Blay et al (2003)	Clinical trial	30	Implant surgery	Not specified	OCT; FBC	Restrict aspiration protocol	Not estimated	Bone structure preserved; collected debris contained large number of osteocytes within the calcified matrix	Qualitative microbiological evaluation showed the presence of normal microbiologic environment of the oral and oral-pharyngeal cavity
Glaser et al (2004)	Clinical trial	50	Drilling	Not specified	KF	Restrict aspiration protocol	Not examined	Not examined	Aerobic (435,000 CFU) and anaerobic (1,013,000 CFU)
Gruber et al (2005)	In vitro study	2	Drilling	Maxilla and mandible	FBC	Not specified	Not examined	After 2 weeks of culture, 487± 413 cells/mg of bone dust	Not examined
Kuttenberger et al (2005)	Clinical trial	39	Implant surgery	Not specified	OCT	Restrict aspiration protocol	Not examined	Not examined	Microbial contamination of 82.7% of samples without chlorhexidine rinse; microbial contamination of 33.3% of microbial contamination with chlorhexidine rinse
Kürkcü et al (2005)	In vitro study	25	Drilling	Mandible	FBC	Restrict aspiration protocol	Not examined	Not examined	Test group (chlorhexidine rinse): $1.5 \times 10^8$ CFU/g; control group, $1.5 \times 10^9$ CFU/g
Pradel et al (2005)	In vitro study	20	Drilling	Maxilla and mandible	FA	Restrict aspiration protocol	Not examined	Cell growth in 65% of bone-sludge cultures. Cells able to proliferate and differentiate in subculture	Not examined
Young et al (2001)	Clinical trial	24	Implant surgery	Not specified	FBC	Stringent aspiration protocol/Non-stringent aspiration protocol	Not examined	Not examined	S: $4071 \times 10^5$ CFU NS: $9634 \times 10^5$ CFU
Young et al (2002)	Clinical trial	20	Implant surgery	Not specified	FBC	Restrict aspiration protocol	Not examined	Not examined	Test group (chlorhexidine rinse): $0.72 \times 10^5$ CFU; control group: $3.43 \times 10^5$ CFU
Young et al (2002)	Clinical trial	38	Implant surgery	Maxilla and mandible	OCT; FBC	Restrict aspiration protocol	Single-tooth maxillary implant (0.031 g OCT; 0.054 g FBC); multiple maxillary implants (0.34 g OCT; 0.088 g FBC); multiple mandibular implants (0.14 g OCT, 0.061 g FBC)	FBC: samples were 92% to 100% bone; OCT: samples were 0% to 85% bone	Not examined
Savant et al (2001)	Clinical trial	9	Implant surgery	Maxilla and mandible	IM	Restrict aspiration protocol	0.195 mL of bone obtained from a site $4.0 \times 1.3$ mm	Not examined	Not examined
Springer et al (2004)	In vitro study	48 (all study) 24 (bone traps)	Drilling with: A: diamond ball drill B: implant drill C: ball reamer	Mandible or iliac crest	Not specified	Not specified	Not examined	Cell count gained from 0.5 mg from each sample after 4 weeks of culture: A: 428,990; B: 150,000; C: 91,400. Milling process reduced the quantity of osteoblasts	Not examined

OCT = Osseous Coagulum Trap (Quality Aspirators; Duncanville, TX); FBC = Frios bone collector (Friatec, Mannheim, Germany); KF = Knochenfilters KFT2 (Schlumbohm OHG, Brokstedt, Germany); IM = IMTEC bone collector (Ardmore, OK); Fa = FA (Sulzer-Medica, Freiburg, Germany).

curettes showed a higher cell viability for the latter. Cell growth approximately doubled when cells were obtained through curettage compared to filtering when the source was spongy bone.<sup>4</sup> This difference was less evident when cortical bone was collected by the 2 methods.<sup>4</sup> Furthermore, osteoblast-like cells derived from filtered material showed a lower capacity to proliferate than cells from chiseled bone, with 18 days needed to observe cell outgrowth compared to 8 in the chiseled-bone group.<sup>25</sup>

Cell differentiation assays indicated that osteoblast-like cells obtained with bone collectors were able to produce alkaline phosphatase,<sup>1,4,25</sup> osteocalcin,<sup>4,25</sup> and collagen I.<sup>25</sup> No significant differences were reported between these cells and cells obtained through curettage or chiseling in terms of cell differentiation.<sup>1,4,25</sup>

### Bacterial Contamination of the Bone Debris Collected

Bacterial contamination of bone debris collected was analyzed in 6 studies.<sup>21–23,26–28</sup> Bacterial contamination was consistently noted.

Quantitative analysis showed basal bacterial contamination of collected bone debris of  $9.63 \times 10^5$  colony-forming units (CFU).<sup>22</sup> Qualitatively, potentially pathological bacterial species were identified. Specific aerobic species included *Enterococcus faecalis*, *Staphylococcus epidermidis*,<sup>22,23</sup> *Staphylococcus aureus*,<sup>21,23,28</sup> *Streptococcus α-hemolyticus*, and *Streptococcus β-hemolyticus*.<sup>21,28</sup> Within the anaerobic group, *Actinomyces odontolyticus*,<sup>22,23,26,28</sup> *Prevotella intermedia*,<sup>21–23,26</sup> *Propionibacterium propionicum*, *Peptostreptococcus asaccharolyticus*,<sup>22,23</sup> *Peptostreptococcus micros*, and *Eubacterium* species,<sup>22</sup> were observed.

Contamination was shown to be significantly reduced by judicious precautions. The use of a restricted aspiration protocol, which involved a dedicated salivary suction device, achieved a reduction in bacterial count of 58% (from  $9.63 \times 10^5$  to  $4.07 \times 10^5$  CFU).<sup>24</sup>

The overall bacterial load can also be reduced with a 2-minute rinse of 0.2% chlorhexidine preoperatively. Using different experimental protocols, observed bacterial load decreases ranged from 3-fold (from  $3.43 \times 10^5$  CFU to  $0.72 \times 10^5$  CFU)<sup>23</sup> to 10-fold (from  $1.5 \times 10^9$  CFU/g to  $1.5 \times 10^8$  CFU/g).<sup>27</sup> Significantly, the anaerobic counts decreased from  $2.34 \times 10^7$  to  $1.02 \times 10^5$ .<sup>27</sup> A preoperative chlorhexidine rinse eliminated pathogens such as *A odontolyticus*, *P intermedia*, *E faecalis*, and *Clostridium bifementans*, whereas contradictory results were reported for *Fusobacterium* species.<sup>23,27</sup>

Rinsing the bone particulate with 200 mL of a 0.1% chlorhexidine solution significantly reduced

microbial contamination. When the collector was not rinsed with chlorhexidine, microbial contamination was found in 82.7% of the samples, and 37 different microbial species were identified in culture. However, when the collector was rinsed with chlorhexidine, only 33.3% of the samples were contaminated, and only 11 species were found, mostly streptococci.<sup>28</sup>

## DISCUSSION

This systematic review assessed the material amassed in bone collectors in terms of quantity, quality, and bacterial contamination. Although bone collectors were capable of acquiring bone, the quality of the collected bone was variable, and consistent bacterial contamination was detected.

Bone collectors are designed to gather the relatively small amounts of bone produced during implant site preparation.<sup>20,24</sup> Clinically, the amount of bone material collected appears to be sufficient to cover small peri-implant bone defects such as fenestrations and dehiscences. However, the small amount of particulate bone that is obtained often necessitates the use of the collected debris in combination with xenografts or alloplastic materials to provide sufficient material to fill defects. This undermines the economical advantage of bone collectors. Not surprisingly, bone quantity increases when multiple implant sites are prepared.<sup>20,24</sup> The quantity of collected bone seems to depend neither on the site of implant placement (mandible versus maxilla) nor on the age or gender of the patient.<sup>20</sup>

The amount of collected bone may be influenced by the net filter mesh diameter.<sup>29,30</sup> Since filter blockage could occur because of excess coagulum, bone collectors cannot be accurately assessed by nonclinical studies. Indeed, pore size affected both the clinical performance and histological composition of the debris collected, because bigger pore size retained larger bone particles and avoided the accumulation of excess coagulum. Indeed, different bone collectors produce different amounts of bone. Smaller-diameter meshes yielded a larger proportion of coagulum within in the collected material and often became blocked.<sup>24</sup>

Ideally, a grafting material should not only be sufficient in terms of quantity but should also contain vital bone-forming cells. It is important to determine whether this property is compromised by the aspiration process. When bone particulate vitality was analyzed, osteoblast-like cells were shown to express alkaline phosphatase and osteocalcin, which are markers of osteogenic cell differentiation.<sup>1,4</sup> Data from these studies confirmed the presence of osteoblast-

like cells which could proliferate and differentiate along the osteogenic lineage, suggesting that they are capable of contributing to bone regeneration following transplantation. However, cell outgrowth was observed in only approximately half of all collected bone samples.<sup>1,25</sup> This can be explained by the small number of cells present in cortical bone or by the damage inflicted to the cells during the drilling and aspiration process. Indeed, *in vitro* studies have shown that bone milling can reduce the quantity of osteoblasts; in one study, the debris obtained from the drill following the use of hard alloy ball reamers resulted in the least amount of viable cells compared to unmilled bone.<sup>4</sup> In addition, frequently found bacterial contamination may decrease the amount of cellular outgrowth from the collected material.<sup>25</sup>

Histologic assessment of the osteogenic and osteoinductive capacity of the collected bone is fundamental in determining the clinical value of utilizing bone traps. Only 1 clinical study has reported the presence of new bone matrix at the grafted site after 6 to 8 months.<sup>21</sup> However, bearing in mind that the collected bone debris frequently contains no viable bone cells, this result, interpreted by the authors as demonstrating the osteogenic potential of the original bone graft, could also be explained by the osteoconductive properties of a nonvital graft, which could act as a scaffold and maintain space for subsequent fill by viable surrounding bone cells.

Bacterial contamination of the graft is an important factor in determining graft and implant survival.<sup>25,31–36</sup> Collected bone debris contained significant levels of bacteria, and this represents a significant disadvantage in using bone collectors.<sup>21–23,26,27</sup> Microbial analysis identified a large number of common saprophytes, including different species associated with a wide range of infections.

A stringent aspiration protocol, combined with the adjunctive use of a preoperative chlorhexidine oral rinse, can considerably reduce the contamination levels in the collected debris.<sup>22–24,26,28</sup> Rinsing the bone particulate with chlorhexidine solution can also significantly decrease microbial contamination, but no data are available on the effects of this type of rinsing on cell vitality.<sup>28</sup> Nevertheless, bacterial contamination remains a significant limitation which has not yet been fully overcome. Therefore, measures should be taken to disrupt the biofilm preoperatively, and a stringent aspiration protocol is recommended when bone debris is collected in the oral cavity.<sup>22</sup> In the context of minimizing bacterial contamination, a possible alternative to bone collectors is the use of bone scrapers,<sup>37,38</sup> which allow clinicians to collect autologous bone shavings from the cortical surface in the vicinity of the surgical site.

In conclusion, the available evidence suggests that the use of bone collectors can yield grafting material which can be used to augment small peri-implant defects. However, despite various disinfection protocols, bone obtained through filtering always shows the presence of pathologic bacterial species. In addition, the presence of vital bone-forming cells is not a consistent finding in collected bone. Therefore, the limited available evidence regarding the use of bone collectors suggests that the resultant grafting material is less than ideal. Unless different methods to avoid bacterial contamination or different device designs are developed, clinicians should be cautious in the use of bone collectors.

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## REFERENCES

1. Gruber R, Baron M, Busenlechner D, Kandler B, Fuerst G, Watzek G. Proliferation and osteogenic differentiation of cells from cortical bone cylinders, bone particles from mill, and drilling dust. *J Oral Maxillofac Surg* 2005;63:238–243.
2. Kubler A, Neugebauer J, Oh JH, Scheer M, Zoller JE. Growth and proliferation of human osteoblasts on different bone graft substitutes: An *in vitro* study. *Implant Dent* 2004;13:171–179.
3. Misch CE, Dietsch F. Bone-grafting materials in implant dentistry. *Implant Dent* 1993;2:158–167.
4. Springer IN, Terheyden H, Geiss S, Harle F, Hedderich J, Acil Y. Particulated bone grafts—Effectiveness of bone cell supply. *Clin Oral Implants Res* 2004;15:205–212.
5. Carinci F, Farina A, Zanetti U, et al. Alveolar ridge augmentation: A comparative longitudinal study between calvaria and iliac crest bone grafts. *J Oral Implantol* 2005;31:39–45.
6. Kessler P, Thorwarth M, Bloch-Birkholz A, Nkenke E, Neukam FW. Harvesting of bone from the iliac crest—Comparison of the anterior and posterior sites. *Br J Oral Maxillofac Surg* 2005;43:51–56.
7. Shirota T, Ohno K, Motohashi M, Michi K. Histologic and micro-radiologic comparison of block and particulate cancellous bone and marrow grafts in reconstructed mandibles being considered for dental implant placement. *J Oral Maxillofac Surg* 1996;54:15–20.
8. Mazock JB, Schow SR, Triplett RG. Proximal tibia bone harvest: Review of technique, complications, and use in maxillofacial surgery. *Int J Oral Maxillofac Implants* 2004;19:586–593.
9. Lundgren S, Nystrom E, Nilson H, Gunne J, Lindhagen O. Bone grafting to the maxillary sinuses, nasal floor and anterior maxilla in the atrophic edentulous maxilla. A two-stage technique. *Int J Oral Maxillofac Surg* 1997;26:428–434.

10. Wiltfang J, Schultze-Mosgau S, Nkenke E, Thorwarth M, Neukam FW, Schlegel KA. Onlay augmentation versus sinus lift procedure in the treatment of the severely resorbed maxilla: A 5-year comparative longitudinal study. *Int J Oral Maxillofac Surg* 2005;34:885–889.
11. Nkenke E, Weisbach V, Winckler E, et al. Morbidity of harvesting of bone grafts from the iliac crest for preprosthetic augmentation procedures: A prospective study. *Int J Oral Maxillofac Surg* 2004;33:157–163.
12. Sindet-Pedersen S, Enemark H. Reconstruction of alveolar clefts with mandibular or iliac crest bone grafts: A comparative study. *J Oral Maxillofac Surg* 1990;48:554–558.
13. Marx RE, Morales MJ. Morbidity from bone harvest in major jaw reconstruction: A randomized trial comparing the lateral anterior and posterior approaches to the ilium. *J Oral Maxillofac Surg* 1988;46:196–203.
14. Dayoub MB. A new filter for osseous coagulum collection. *J Periodontol* 1981;52:45–46.
15. Hutchinson RA. Osseous coagulum collection filter. *J Periodontol* 1973;44:688–690.
16. Solomons NB, Robinson JM. Obliteration of mastoid cavities using bone pate. *J Laryngol Otol* 1988;102:783–784.
17. Solomons NB, Robinson JM. Bone pate repair of the eroded incus. *J Laryngol Otol* 1989;103:41–42.
18. Roldan JC, Jepsen S, Schmidt C, et al. Sinus floor augmentation with simultaneous placement of dental implants in the presence of platelet-rich plasma or recombinant human bone morphogenetic protein-7. *Clin Oral Implants Res* 2004;15:716–723.
19. Widmark G, Ivanoff CJ. Augmentation of exposed implant threads with autogenous bone chips: Prospective clinical study. *Clin Implant Dent Relat Res* 2000;2:178–183.
20. Savant TD, Smith KS, Sullivan SM, Owen WL. Bone volume collected from dental implant sites during osteotomy. *J Oral Maxillofac Surg* 2001;59:905–907.
21. Blay A, Tunchel S, Sendyk WR. Viability of autogenous bone grafts obtained by using bone collectors: Histological and microbiological study. *Pesqui Odontol Bras* 2003;17:234–240.
22. Young MP, Carter DH, Worthington H, Korachi M, Drucker DB. Microbial analysis of bone collected during implant surgery: A clinical and laboratory study. *Clin Oral Implants Res* 2001;12:95–103.
23. Young MP, Korachi M, Carter DH, Worthington HV, McCord JF, Drucker DB. The effects of an immediately pre-surgical chlorhexidine oral rinse on the bacterial contaminants of bone debris collected during dental implant surgery. *Clin Oral Implants Res* 2002;13:20–29.
24. Young MP, Worthington HV, Lloyd RE, Drucker DB, Sloan P, Carter DH. Bone collected during dental implant surgery: A clinical and histological study. *Clin Oral Implants Res* 2002;13:298–303.
25. Pradel W, Tenbrieg P, Lauer G. Influence of harvesting technique and donor site location on in vitro growth of osteoblast like cells from facial bone. *Int J Oral Maxillofac Implants* 2005;20:860–866.
26. Glaser B, Hodel Y, Meyer J, Lambrecht JT. Bacterial contamination of bony particles from the bone collection trap. *Schweiz Monatsschr Zahnmed* 2004;114:337–341.
27. Kürkçü M, Oz IA, Koksal F, Benlidayi ME, Gunesli A. Microbial analysis of the autogenous bone collected by bone filter during oral surgery: A clinical study. *J Oral Maxillofac Surg* 2005;63:1593–1598.
28. Kutenberger JJ, Hardt N, Rutz T, Pfyffer GE. Bone collected with a bone collector during dental implant surgery. *Mund Kiefer Gesichtschir* 2005;9:18–23.
29. Kainulainen V, Oikarinen K. Comparison of four bone collectors designed for oral and maxillofacial surgery—An in vitro study. *Clin Oral Implants Res* 1998;9:327–332.
30. Oikarinen K, Kainulainen V, Kainulainen T. A method of harvesting corticocancellous bone chips for reconstructive maxillofacial surgery. *Int J Oral Maxillofac Surg* 1997;26:103–105.
31. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (II). Etiopathogenesis. *Eur J Oral Sci* 1998;106:721–764.
32. Esposito M, Hirsch J, Lekholm U, Thomsen P. Differential diagnosis and treatment strategies for biologic complications and failing oral implants: A review of the literature. *Int J Oral Maxillofac Implants* 1999;14:473–490.
33. Lindeboom JA, van den Akker HP. A prospective placebo-controlled double-blind trial of antibiotic prophylaxis in intraoral bone grafting procedures: A pilot study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2003;96:669–672.
34. Mombelli A. Microbiology and antimicrobial therapy of peri-implantitis. *Periodontol* 2000 2002;28:177–189.
35. Quirynen M, Gijbels F, Jacobs R. An infected jawbone site compromising successful osseointegration. *Periodontol* 2000 2003;33:129–144.
36. Tonetti MS, Schmid J. Pathogenesis of implant failures. *Periodontol* 2000 1994;4:127–138.
37. Artzi Z, Kozlovsky A, Nemcovsky CE, Weinreb M. The amount of newly formed bone in sinus grafting procedures depends on tissue depth as well as the type and residual amount of the grafted material. *J Clin Periodontol* 2005;32:193–199.
38. Peleg M, Garg AK, Misch CM, Mazor Z. Maxillary sinus and ridge augmentations using a surface-derived. *J Oral Maxillofac Surg* 2004;62:1535–1544.