Davide Zaffe
Ferdinando D'Avenia

A novel bone scraper for intraoral harvesting: a device for filling small bone defects

Authors' affiliations:
Davide Zaffe, Department of Anatomy and Histology, Section of Human Anatomy, University of Modena and Reggio Emilia, Modena, Italy
Ferdinando D'Avenia, Private Practice, Parma, Italy

Correspondence to:
Prof. Davide Zaffe
Dipartimento di Anatomia e Istologia
Sezione di Anatomia Umana
Via Del Pozzo, 71- 41100 Modena, Italy
Tel.: +39-0594224800
Fax: +39-0594224861
e-mail: zaffe@unimore.it

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Key words: autologous bone, bone chips, bone collector, bone defect healing, bone graft, histology, remodeling

Abstract

Aim: To evaluate histologically the morphology and characteristics of bone chips harvested intraorally by Safescraper®, a specially designed cortical bone collector.

Material and methods: Bone chips harvested near a bone defect or in other intraoral sites were grafted into a post-extractive socket or applied in procedures for maxillary sinus floor augmentation or guided bone regeneration. Core biopsies were performed at implant insertion. Undecalcified specimens embedded in PMMA were studied by histology, histochemistry and SEM.

Results: Intraoral harvesting by Safescraper® provided a simple, clinically effective regenerative procedure with low morbidity for collecting cortical bone chips (0.9–1.7 mm in length, roughly 100 μm thick). Chips had an oblong or quadrangular shape and contained live osteocytes (mean viability: 45–72%). Bone chip grafting produced newly formed bone tissue suitable for implant insertion. Trabecular bone volume measured on biopsies decreased with time (from 45–55% to 23%). Grafted chips made up 50% or less of the calcified tissue in biopsies. Biopsies presented remodeling activities, new bone formation by apposition and live osteocytes (35% or higher).

Discussion and conclusions: In conclusion, Safescraper® is capable of collecting adequate amounts of cortical bone chips from different intraoral sites. The procedure is effective for treating alveolar defects for endosseous implant insertion and provides good healing of small bone defects after grafting with bone chips. The study indicates that Safescraper® is a very useful device for in-office bone harvesting procedures in routine peri-implant bone regeneration.

Bone grafting is a common management option for treating bone defects and reconstructing alveolar bone before implant insertion. Homologous, xenologous, heterologous or synthetic grafting material all have some drawbacks, even if they have a distinctive feature: availability on demand. Autologous bone is the 'gold standard' for bone grafting (Jakse et al. 2001; Gamradt & Lieberman 2003; Mazock et al. 2004), as it does not produce adverse reactions and has optimal biocompatible remodeling patterns (Matsuda et al. 1992) and osteoinductive capabilities (Bunger et al. 2003; Hu et al. 2004). Bone has been used in blocks (Jensen & Sindet-Pedersen 1991; Misch et al. 1992; Sethi & Kaus 2001; Zerbo et al. 2003) or particulates (Missori et al. 2002; Schlegel et al. 2003; Artzi et al. 2005; Le Lorc'h-Bukiet et al. 2005), alone (Missori et al. 2002; Schlegel et al. 2003; Le Lorc'h-Bukiet et al. 2005), under a membrane-

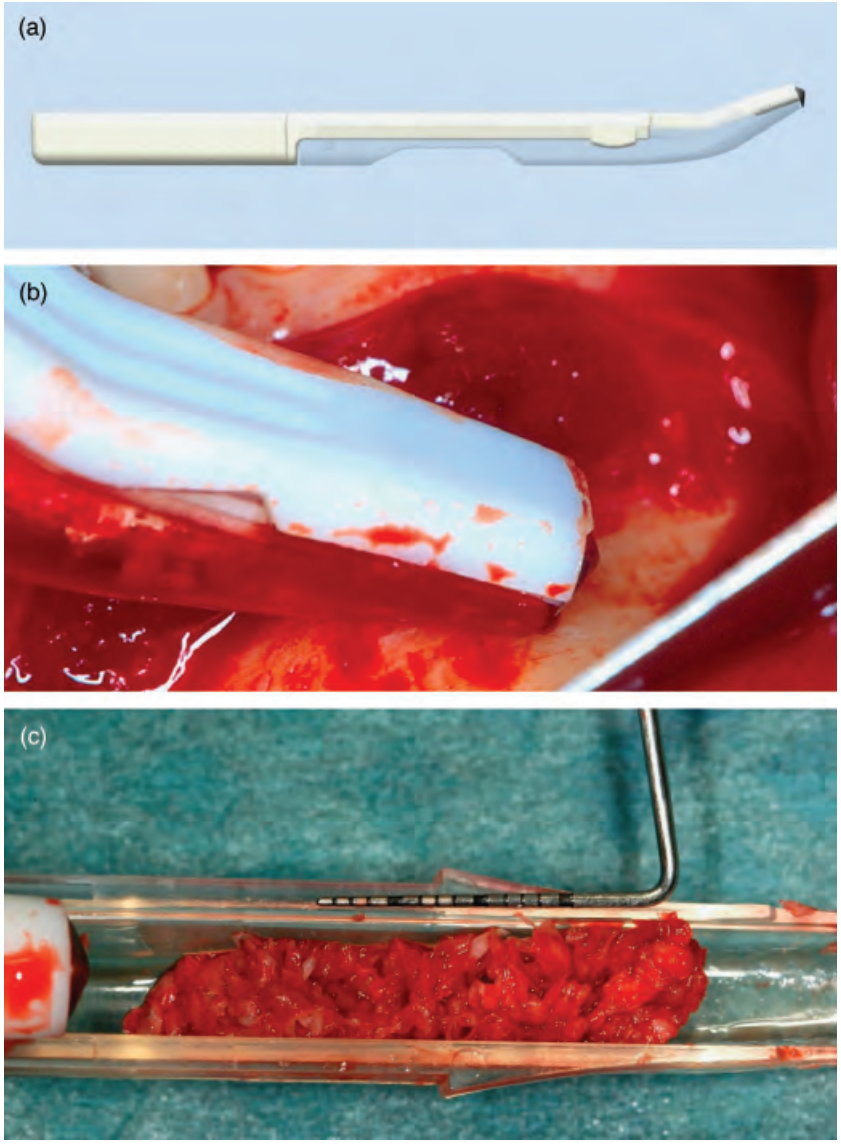

Fig. 1. Schematic illustration (a) of the Safescraper® curve. Bone harvesting (b) during guided bone regeneration procedure in a 47-year-old man for a dehiscence defect of an implant in region 13. The same access flap can be used for reconstructive surgery and bone harvest, with significant post-operative benefits for the patient. Bone chips (c) collected by Safescraper® that simultaneously harvests, processes and store bone chips.

protected space in guided bone regeneration (GBR) procedure Dahlin et al. 1988; (Buser et al. 1990; Simion et al. 1994) or mixed with other graft materials (Hallman et al. 2002; Hatano et al. 2004; Turunen et al. 2004; Artzi et al. 2005). A controversy remains as to whether cortical or spongy bone is the material of choice for autologous bone grafts (Girdler & Hosseini 1992; Schwipper et al. 1997).

Large defects undoubtedly require great amounts of bone that can only be harvested from extraoral donor sites, such as the iliac crest (Jin et al. 2004; Kinsel & Turbow 2004; Turunen et al. 2004), tibia (Jakse et al. 2001; Mazock et al. 2004) or head (Al Sebaei et al. 2004; Le Lorc'h-Bukiet et al. 2005). Smaller defects can be treated with limited bone volumes that can be harvested intraorally, also exploiting lower resorption (Smith & Abramson 1974; Zins & Whitaker 1983; Borstlap et al. 1990), enhanced vascularization (Zins & Whitaker 1983) and better incorporation (Borstlap et al. 1990) of bone grafts of membranous as compared with endochondral origin.

Several methods are available for harvesting particulate bone (Hallman et al. 2002; Missori et al. 2002; Schlegel et al. 2003; Hatano et al. 2004; Turunen et al. 2004; Artzi et al. 2005; Le Lorc'h-Bukiet et al. 2005), but almost all have some drawbacks. The most common method is to mill large bone portions (Erpenstein et al. 2001; Cordaro 2003; Springer et al. 2004; Le Lorc'h-Bukiet et al. 2005). Treatment of transplants with the bone mill or lifting transplants by rotating electrical instruments appears to reduce the amount of viable bone cells supplied (Springer et al. 2004). Some authors collect bone during implant surgery (Widmark & Ivanoff 2000; Young et al. 2002b), but they need an implant site. Surgical requirements cannot always be met in the dental office and some types of bone treatments, such as milling, surely impoverish bone qualities (Springer et al. 2004). Moreover, bone harvesting and treatment may suffer from microbial contamination (Young et al. 2001, 2002a). The use of a bone collector represents an uncommon technique. Bone collectors were proposed many years ago (Feenstra & Uges 1978; Jackson et al. 1988) but they have been continuously redesigned, renewed, studied and proposed to achieve the most effective and practical use (Kainulainen & Oikarinen 1998; Al Sebaei et al. 2004).

The aim of this work was to study cortical bone particles harvested from intraoral sites of consenting patients using a new type of bone-harvesting device. Histology, microradiography and SEM analyses were performed on the viability and behavior of cortical bone particles, before and after their use in extraction sockets, under e-PTFE membrane-protected alveolar bone defects or in the augmentation of the maxillary sinus floor to characterize this technique, which may represent a useful method for bone harvesting in the office.

Materials and methods

Bone harvester design

A disposable, manual cortical bone-harvesting device was used (Safescraper® curve, Meta, Reggio Emilia, Italy). The harvester (Fig. 1a) consist of a blade, body and collection chamber: the surgical-grade stainless-steel blade (conforming to EN ISO 7153-1) is thermally treated to improve its mechanical properties, with the geometry optimized for greater cutting control and strength that can harvest bone chips up to

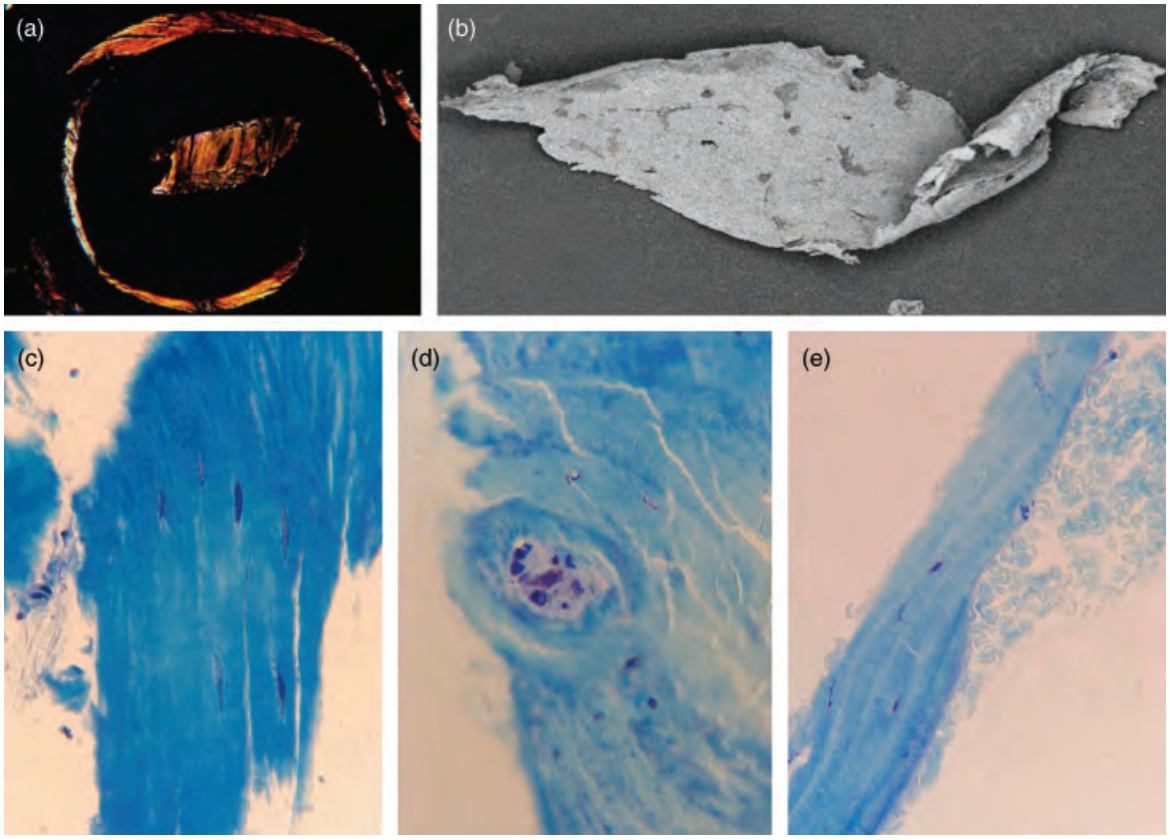

Fig. 2. Morphology (a, polarized light, trypan blue stain; b, SEM; c–e, toluidine blue stain) of bone chips collected by Safescraper®. Note the curved shape of some elongated chips in (a). Small cracks are visible inside some chips (a and c). Live osteocytes can be observed inside large (c) and thin (e) chips. The content of a haversian canal of a bone chip, containing live osteoblasts, is displayed in (d). Field width a = 2660 μm; b = 5000 μm; c = d = 125 μm; e = 200 μm.

5 ml in length in a single scoop (Fig. 1b). The main body is made of polyoxymethylene, chemically atoxic according to the European Pharmacopoeia. The 2-ml chamber in transparent MABS stores the collected bone in a protected environment (Fig. 1c).

Surgery

Eighteen male patients, mean age 54.7 years, requiring bone augmentation, were selected after application of strict inclusion criteria (Consolo et al. 2006). All patients gave informed consent to the procedure.

Using the harvester (Safescraper® curve), bone was collected on surfaces adjacent to the defects to fill post-extractive (second premolar) defects in eight patients (44.4%) and near the external oblique ridge for sinus lifting and GBR augmentations, needing 3 ml or more of scraped bone, in the remaining 10 patients (55.6%). Raising a full-thickness mucoperiosteal flap accessed the donor site, and bone was harvested by repeatedly drawing the harvester (Safescraper® curve) over the exposed bone surface. Bone chips in excess were kept for histology.

Post-extractive defects

Bone chips were packed by overfilling the alveolus about 1 mm over the vestibular edge wall. The vestibular flap was released with periosteal incisions and coronally sutured, creating the primary wound roof.

Augmentation of the maxillary sinus floor

A conventional lateral access was performed as described by Tatum (Boyne & James 1980) in six patients whose edentulous area extended three to four adjacent teeth distal to the maxillary canine and whose residual bone thickness of the maxillary floor was lower than 4 mm. The schneiderian membrane was gently raised and the collected bone chips were used to pack the cavity over the extension of the edentulous area.

GBR

The procedure was performed on four patients having an edentulous ridge three to four teeth in length and severe horizontal and vertical alveolar defects that ruled out an immediate implant insertion. The collected bone chips (Safescraper® curve) were covered by a non-reinforced (Gore GT10) or titanium-reinforced (Gore TR9W) expanded e-PTFE membrane (WL Gore, Flagstaff AZ, USA) following the Buser protocol (Buser et al. 1993, 1995).

Sutures were removed 10–12 days after reconstructive surgery. A monthly follow-up was scheduled to check for wound dehiscence up to the time of implant insertion. A bone-core biopsy was obtained before implant insertion by means of a trephine bur (3.5 mm external diameter, ACE Surgical Supply Company, Brockton MA, USA) under a saline jet.

Implant insertion was performed after 3–4 months (post-extractive defects – MK III TiU Branemark System, Nobel Biocare AB, Goteborg, Sweden or Replace Select Tapered TiU, Nobel Biocare AB), after 4–6 months (sinus lift – Replace Select Tapered) and after 9 months (GBR – MK III TiU) from surgery utilizing conventional rotary instruments.

Histology

Bone chips harvested using the manual collection tool (Safescraper® curve) were

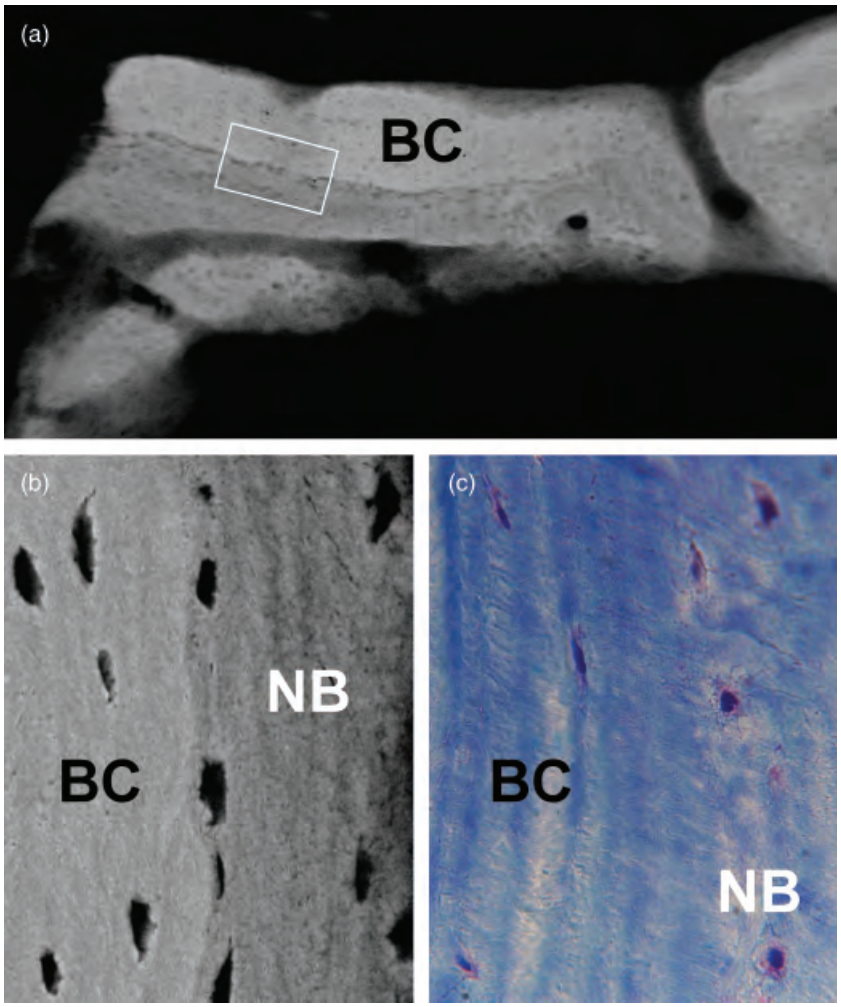

Fig. 3. Microradiograph (a) and back-scattered SEM image (b) of the same thick section, and toluidine blue stained (c) section (cut immediately before the thick section) of the same biopsy of bone chips, collected by Safescraper®, grafted into the post-extractive socket of the mandible, 4 months after surgery. The boxed-in area corresponds to a higher magnification of images reported in (b) and (c). Note in (a) how the bone chip (BC) is almost completely surrounded by newly formed bone. It has a smooth surface and a vascular channel running through it. Note in (b) and (c) how the lamellar BC, containing typical ellipsoid-shaped (live) osteocytes, continues with the newly formed bone [new bone (NB), darker in (a) and (b)] having a woven structure and displaying irregular-shaped osteocytes, in a disordered array. Field width: a = 1050 μm; b = 135 μm; c = 110 μm.

fixed in 4% paraformaldehyde in 0.1 M phosphate buffer, pH 7.2, for 1 h at room temperature and then dehydrated and PMMA embedded, as reported elsewhere (Consolo et al. 2006). Five micrometer thick sections were obtained from blocks containing bone chips using a bone microtome (Autocut1150, Reichert-Jung, Nuβloc, Germany). Some of the larger bone chips were selected, and desiccated in a critical-point dryer and fastened to SEM stubs (Bertoldi et al. 2005).

Biopsies were fixed in paraformaldehyde, dehydrated and PMMA embedded at 4°C (Consolo et al. 2006). Longitudinal thin (5-μm-thick) and thick (200-μm-thick) sections were obtained and treated as reported in Consolo et al. (2006). Thin sections were stained with toluidine blue, trypan blue, total alkaline phosphatase and tartrate-resistant acid phosphatase methods (Consolo et al. 2006). Thick sections were reduced to 100 μm and X-ray microradiographed (Consolo et al. 2006). Thick sections were fastened on an SEM stub. Some thick sections were etched with 0.1 M HCl for 60 s, gently and accurately washed with distilled water and dried before fastening on an SEM stub. Trabecular bone volume (TBV, index of bone tissue content – Parfitt et al. 1987) was evaluated on microradiographs by means of a suitable image analyzer (VIDAS, Zeiss, Oberkochen, Germany). The stubs, supporting bone chips or PMMA sections were examined under SEM (XL40, Philips, Eindhoven, The Netherlands) after gold sputtering (Bertoldi et al. 2005).

Results

All wounds caused by bone harvest and grafting healed uneventfully, with no infection, early or late dehiscence and temporary or permanent nerve disorder.

At implant insertion, 3–4 months after surgery, the bone chips grafted into post-extractive defects appeared very well integrated, so as to be indistinguishable with the surrounding pre-existing bone. Bone quality, evaluated (Lekholm & Zarb 1985) during the drilling phase with a 3.5 mm external diameter trephine bur, was class 4 in six cases and class 3 in the remaining two, leading in all cases to an implant insertion torque of 40 N, as measured with a calibrated insertion handpiece (Elcomed, W & H, Burmoos, Austria).

In the sinus graft and GBR cases, respectively, 4–6 and 9 months after the bone graft, bone quality appeared to be constantly class 4, but this did not alter the good primary stability for all the 31 positioned implants.

At examination, all the retrieved core biopsies appeared to be composed of vascularized cortical and spongy bone.

Cortical bone chips

Most harvested bone chips had a toothpick appearance, with an elongated quadrangular shape (Fig. 2) and curved arrangement after fixing and embedding. This curving was related to lamellar displacement; bone chips bended when lamellae were obliquely oriented to the cutting surface or if orthogonal were adjacent to tangential lamellae (Fig. 2a). A smaller number of larger quadrangular chips were obtained by scraping (Fig. 2a). These chips showed various lamellar displacements and could present cracks similar to those in lengthened chips (Fig. 2). These large quadrangular chips reached a conspicuous size, even exceeding 5 mm (Fig. 2b), and they generally did not shows internal cracks, as their structural displacement favored intact harvesting.

Most chips contained living cells. Live osteocytes were found not only inside the large quadrangular chips (Fig. 2c) but also

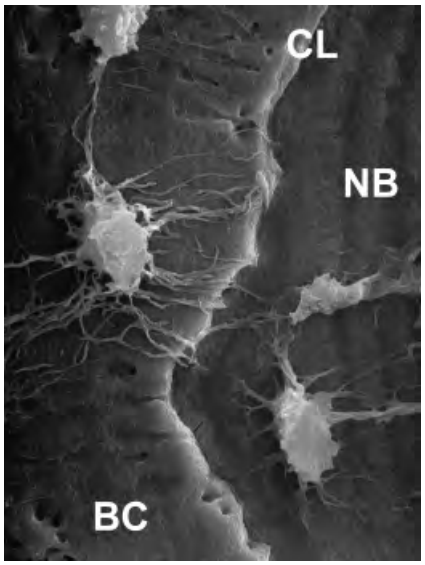

Fig. 4. Secondary electron SEM image of a partially etched thick section of a biopsy of bone chips, collected by Safescraper®, grafted in a GBR procedure of the mandible, 6 months after surgery. Note how the lacuno-canalicular network of the bone chip (BC) is connected to that of the new bone (NB) by some canaliculi, which run through the cement line (CL). Field width 50 μm.

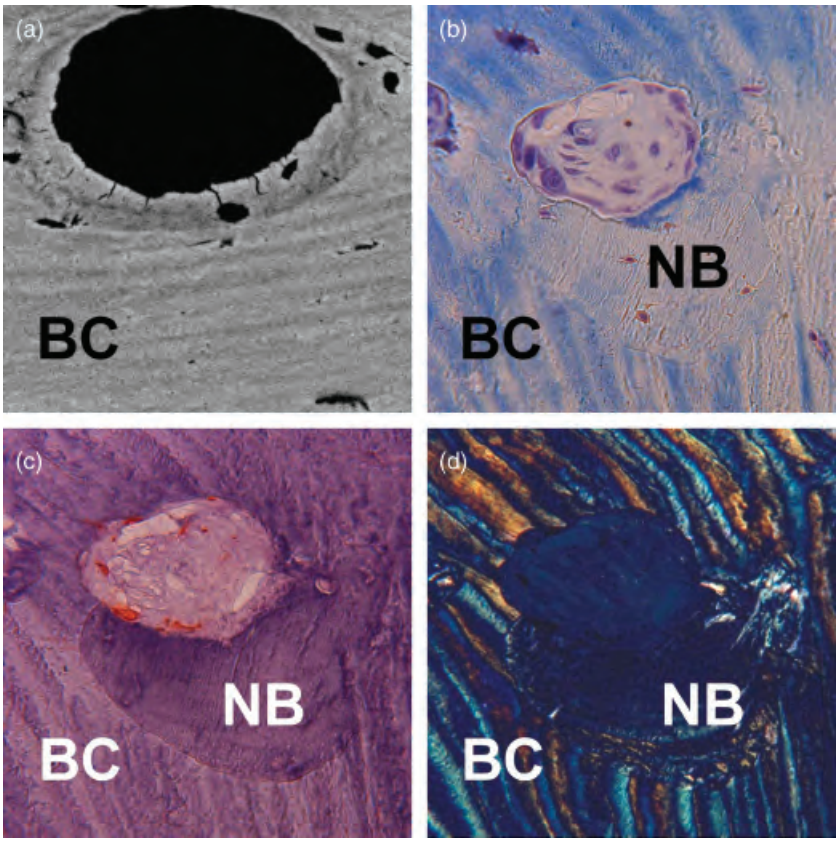

Fig. 5. Back-scattered SEM image (a) of thick, toluidine blue (b) and tartrate resistant acid phosphatase (c, ordinary light; d, polarized light) treated section of the same biopsy of bone chips, collected by Safescraper®, grafted into a post-extractive socket of the mandible, 4 months after surgery. The bone chip (BC), containing the typical ellipsoid-shaped (live) osteocytes, has a lamellar structure. It is eroded, and new bone [NB, darker in (a)] having a woven structure and displaying irregular-shaped osteocytes, was previously formed in apposition to it. Now osteoclasts [red in (c)] resorb both the bone chip and new bone to enlarge the vascular cavity (first step of remodeling). Field width: a = 170 μm; b = c = d = 200 μm.

in the context of thin lengthened quadrangular chips (Fig. 2e). Unroofed lacunae not containing a protoplasm could be observed at the surface of bone chips. Haversian canals with living osteoblasts and stromal cells were occasionally observed inside the chips (Fig. 2d). Moreover, vessels sectioned at various angles were found inside the larger and thicker bone chips.

Morphometrical analysis of bone chips diameters varied widely among patients (nine individuals). The mean length of sectioned bone chips ranged from 0.9 to 1.7 mm. If not manually selected (for instance for study under SEM), embedded and sectioned bone chips seldom exceeded 3 mm in length, even if bone chips longer than 5 mm were observed at SEM (Fig. 2b). Measurements of the width of sectioned bone chips were more homogeneous. In our case series, the mean width ranged from 150 to 250 μm. Nonetheless, width measurements were distributed in is trimodal patterns, with the first peak at around 100 μm; a second peak between 250 and 350 μm; and the third at 500–600 μm width.

The viability of osteocytes of bone chips varied greatly among patients. If we exclude a low mean viability (37.5%) in one patient, the mean viability of the osteocytes of bone chips harvested with the Safescraper® ranged from 45% to 72%.

Bone biopsies

The morphometry of biopsies pointed out that the highest TBV values (ranging from 40% to 55%) were reached 3–4 months after surgery, particularly in extraction sockets of the mandible. In maxillary sites, TBV decreased slightly (30–50%) 4–6 months after surgery, but defined sharply (23%) after 9 months. Grafted bone generally makes up <50% of the calcified tissue detectable 4–5 months after surgery, if we exclude the result in the mandible of one patient (about 80%).

Grafted bone was gradually resorbed over time and replaced by newly formed bone. Erosion initially involved the smaller bone chips, and only large chips, partially eroded or not, may be found later (Fig. 3a). Generally, grafted chips appeared shorter (below 1 mm) and now had a blunted and not the initial sharp profile. Grafted chips had newly formed bone in apposition to the autologous bone surface (Fig. 3b). New bone completely or partially surrounded the grafted chip (Fig. 3a). Some rare chips, surrounded by newly formed bone, presented internal cracks. Many live osteocytes (Fig. 3c) filled the lacunae of grafted bone. Evaluations on 18 biopsies showed a mean value of live osteocytes, variable among patients, ranging from 25% to 60% of grafted chip lacunae. Examination of SEM-etched specimens (Fig. 4) pointed to a reconstruction of the lacuno-canalicular network: along the cement (reversal) line, some connections among canaliculi of grafted chips and new bone were displayed (Fig. 4).

Resorption of grafted chips involved not only the outer surface but also the internal tissue (Figs 3–5). Osteoclasts formed cavities inside the bone chip, most likely widening previously existent vascular cav-

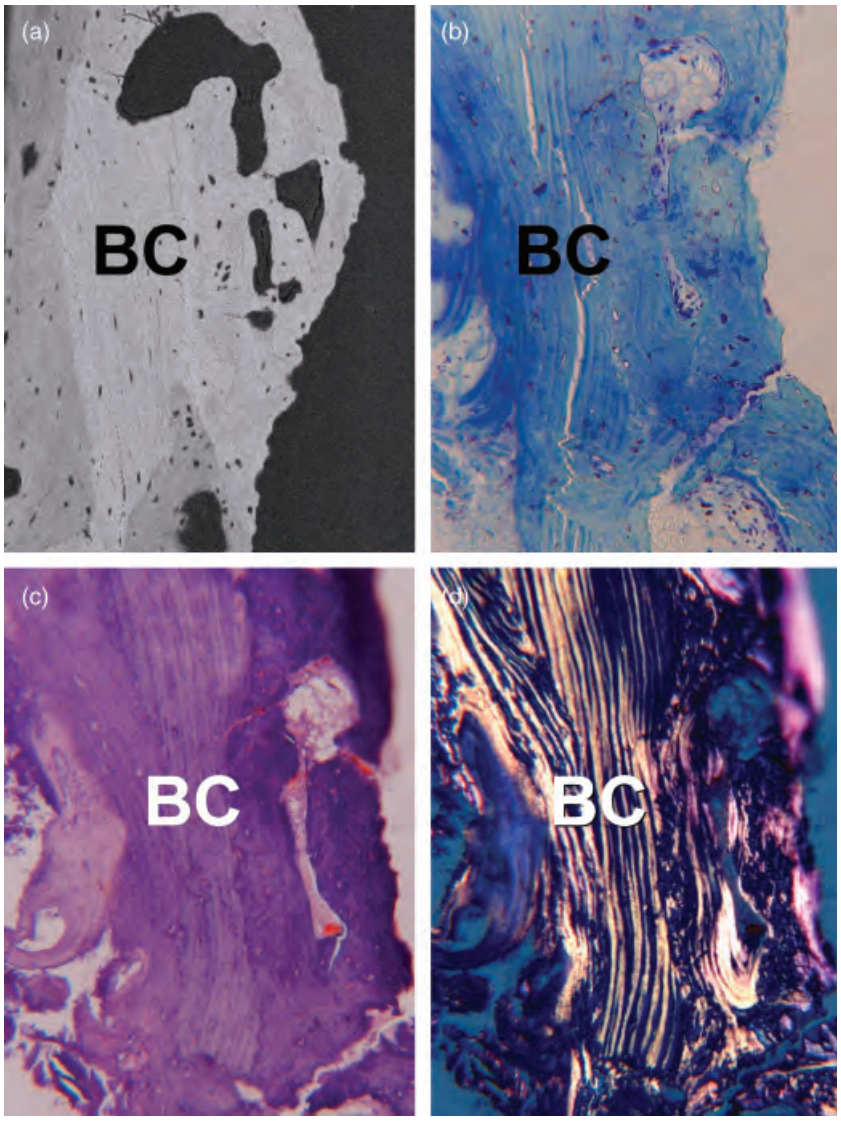

Fig. 6. Back-scattered SEM image (a) of thick, toluidine blue (b) and tartrate resistant acid phosphatase (c, ordinary light; d, polarized light) treated section of the same biopsy of bone chips, collected by Safescraper®, grafted in a guided bone regeneration procedure of the mandible, 9 months after surgery. The bone chip (BC) has a lamellar structure (d) containing live osteocytes (b). It is completely surrounded by new bone [darker in (a)], with woven structure (d). The BC is eroded, but here erosion cavities, some containing active osteoclasts [(b), red in (c)], are mainly visible inside the newly formed bone. Field width: a = 170 μm; b = c = d = 200 μm.

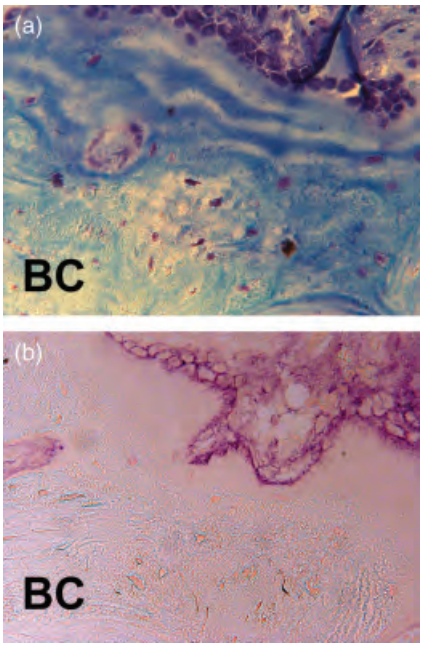

Fig. 7. Toluidine blue (a) and total alkaline phosphatase (TALP) (b) treated section of a biopsy of bone chips, collected by Safescraper®, grafted in a guided bone regeneration procedure of the mandible, 9 months after surgery. Active osteoblasts, positive to TALP, continue to form new bone in apposition to the bone chip (BC) residue to adapt the skeletal site to loads. Field width: a = b = 400 μm.

ities. Woven bone can form on the reversal line of bone chips (Fig. 3). Osteoclasts (Fig. 5c) can successively erode both the newly formed bone and grafted bone, widening the cavity, and successively osteoblasts can fill the cavity with new bone, most likely lamellar in structure.

If bone chips were initially large in size, some residues of grafted chips could be found a long time after surgery (Fig. 6). Grafted bone appeared highly resorbed by osteoclast activities (Fig. 6a) and completely surrounded by bone (Fig. 6). Live osteocytes (about 35% of whole lacunae) were observed inside grafted chips. Osteoclasts seemed to prefer to erode newly formed woven bone rather than grafted bone (Fig. 6c). Some osteogenetic activities (Fig. 7) continued to form new bone, mainly lamellar, in apposition to residues of grafted chips even 9 months after surgery.

Discussion

All patients enrolled in this study required bone augmentation before three-dimensional implant placement (Salama et al. 1998; Saadoun et al. 1999; Tarnow et al. 2003) in accordance with a prosthetically driven treatment plan (Mecall & Rosenfeld 1992; Buser & Belser 1994; Kois & Kan 2001). Intraoral bone harvesting, with cortical chips reaching 10 – 15 ml volumes for the ramus donor site, was able to achieve a valid functional and aesthetic prosthetic restoration in all patients, meeting the reconstructive goals. A total of 39 implants were placed in three different types of alveolar defects, with a 100% success rate at the moment of prosthetic delivery. The biological characteristics of these defects and their healing potential were quite varied (Tinti & Parma-Benfenati 2003), as this study included small self-contained three to four wall bone defects (alveolar defects), large self-contained four wall defects (sinus grafts) and medium to large non-self-containing bone defects (horizontal and vertical GBR cases). Especially for the last group and for vertical ridge augmentation, the osteogenic potential of the grafting material plays a major role in the clinical outcome of the regenerative procedure (Simion et al. 1998). Nevertheless, a good regenerative activity was obtained for all defect morphologies, leading to a mechanically

stable graft site after bone maturation in all patients.

Our results confirm that bone harvesting with a manual collector (Safescraper® curve) provides good clinical outcomes in extraction socket healing, augmentation of the maxillary sinus floor and GBR procedures. The manual collection tool (Safescraper® curve) furnishes autologous bone, avoiding the need for traditional incision-based techniques and cortico-cancellous bone block harvesting with associated post-operative discomfort (von Arx et al. 2005). The bone-collection procedure harvested good quantities of uncontaminated autologous bone suitable for grafting close the donor site. The high-tech blade of the tool (Safescraper® curve) allows correct shaving of the cortex, irrespective of the bone lamellation, providing bone chips up to 5 mm in length. Collected bone is preserved in a sterile environment until, mixed with blood, it is used to fill bone defects.

The tool (Safescraper® curve) collects elongated or short-quadrangular bone chips. The mean size of the chips was about 1.3 mm in length, 200 μm in width (SEM analyses were performed on selected 3–5 mm chips) and about 100 μm in thickness (the first of the three peaks of the trimodal distribution; the other two peaks correspond to the width of lengthened and short-quadrangular chips).

Owing to remodeling processes, lamellae may lie in different directions in adjacent sites, and cracks in the chips are not surprising. Cracks form when the cutting blade crosses a lamella at a different orientation, offering higher resistance. Cracks do not form when lamellation is continuous. Long chips are collected when lamellae are parallel or slightly oblique to the cutting plane. Owing to the lower resistance of the loose lamellae (Marotti 1993; Marotti et al. 1994), short-narrow chips are formed when lamellae are orthogonal to the cutting plane. Despite the dependence on lamellation, the curved shape of the sectioned chips may be considered an artifact due to fixation and embedding processes. We do not ordinarily observe curved chip forms in biopsies, whereas they are common in sectioned chips. The remarkable absence of cracks in chips analyzed under SEM is strictly related to this observation. Large chips are only harvested when the lamellation of a site is sufficiently uniform, whereas several chips are formed when lamellation is discontinuous. Therefore, cracks are most likely absent in these large chips.

The percent viability of osteocytes in harvested bone chips (ranging from 45% to 70%) probably matches that of the donor site, as the mean percent of live osteocytes in physiologically functional interstitial bone of the femur neck of elderly ranges from 25% to 55% (Palumbo et al. 2001). The observed percent of live osteocytes of bone chips was higher and suggests that harvesting processes had a moderate impact on viability. The recorded decrease in live osteocytes 9 months after surgery agrees with Zerbo et al. (2003), even if these authors found that the majority of osteocytes did not survive in a grafted block bone. This decrease seems to indicate that integration with the lacuno-canalicular network exists, but it was not able to maintain the viability of most chip osteocytes.

Bone chips are destined to total resorption in the grafted site. Nevertheless, bone chips undergo different resorption patterns. All grafted chips were more or less eroded by osteoclasts that act during the first 2–4 months of implant. This greater resorption activity probably removes grafted chips of roughly mean to minimum size. Although reduced in size, only larger chips endure osteoclast resorption. They are surrounded by newly apposed bone and can be recovered 9 months after surgery. Eroded bone releases its component into the environment with an osteoconductive effect that loads to a high TBV 2–4 months after surgery. TBV reduction is not due to weaning off of osteoinductive effects as active bone formation was also found 9 months after surgery, but instead to graft site unloading. Bone amount is inversely related to time 5–9 months after surgery.

In conclusion, the results seem to support the potential for bone harvesting by the Safescraper® tool. Collected bone chips contain live osteocytes, indicating a good quality of the bone harvest. Grafted chips are for the most part resorbed, inducing the formation of appreciable amounts of new bone, but a part of them, still containing live osteocytes, are included in the skeletal tissue of the graft site. The all-in-one concept of this surgical device (harvesting, processing and storing), the possible utilization in different donor sites and the large amounts of bone chips that can be collected make it a useful instrument for regenerative procedures in the office setting.

要旨

目的：特別なデザインの皮質骨採取装置Safescraper®によって口腔内から採取した骨片の形態と特性を組織学的に評価すること

材料と方法：骨欠損の近く、または他の口腔内部位から採取した骨片を抜歯窩に移植するか、上顎洞底増生術または GBR に用いた。インプラント埋入時にコア生検を行った。非脱灰標本を PMMA に包埋し、組織学、組織化学、および SEM によって検討した。

結果：Safescraper® による口腔内の皮質骨片の採取は、合併症率が低く、単純で、臨床的に効果的な再生術式を提供するものである（0.9－1.7mm 長、約 100 ミクロン厚）。骨片は楕円または長方形で、生きた骨細胞を含んでいる（平均生細胞：45-72%）。骨片の移植はインプラント埋入に適した新生骨組織を産生する。生検時に測定した骨梁量は経時的にに減少した（45-44 から 23%に）。手術後 9 ヵ月後の生検で石灰化組織のうち移植骨片は５０％未満であった。生検は、リモデリングの活動、添加と生骨細胞（35%以上）による新生骨の形成を示していた。

考察と結論：結論として、Safescraper®は異なる口腔内部位から十分な量の皮質骨片を採集することができる。同手順は、骨内インプラント埋入のための歯槽骨欠損治療に効果的であり、骨片の移植後小さな骨欠損は良好に治癒する。本研究は、Safescraper®はルーティンに行うインプラント周囲骨再生術において院内での骨採取に非常に有用な装置であることを示している。

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