



Comparative Evaluation of the Radiopacity of Bone Graft Materials used in Dentistry

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ABSTRACT

Introduction: Ample radiopacity in order to distinguish from the surrounding tissues is a desirable property of dental graft materials. A total of 15 bone graft materials' (BGMs) opacities were analyzed in this study.

Materials and methods: Graft materials were placed in the implant cavity (5 × 10 mm) in cadaver's mandible respectively. Cavity was exposed by using periapical film and a dental X-ray machine at 70 kVp and 8 mA. The optical density of the radiographic images was measured with a transmission densitometer. One-way analysis of variance (ANOVA) was conducted for statistical analysis.

Results: Among the materials tested, the most radiolucent bone grafts were Grafton and Allogenix with a statistical significance of $p \geq 0.05$. 4Bone and Bego Oss exhibited the highest radiopacity with a statistical significance of $p \geq 0.05$. Inadequate radiopacity of the dental graft materials may lead to confusion among clinicians in the radiographical follow-up. Among 15 BGMs tested, only three had higher density than bone tissue.

Conclusion: The radiopacity of the BGM was found to be higher than bone at only three of them.

Keywords: Bone graft, Cadaver, Densitometry, Radiopacity.

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INTRODUCTION

Bone graft materials are frequently used in orthopedics, periodontics, and in oral and maxillofacial surgery with effective clinical outcomes.¹ The BGMs that are presently

used in dental clinics are autogenous bones, allogeneic bones, xenogeneic bones, and alloplastic materials.² Although autogenous bone grafts are thought to be the gold standard for bone grafting, it has some disadvantages, such as the formation of a second surgical region, causing morbidity in the donor region, and only being able to take a limited amount.³ The need for an allogeneic source of bone arose from the need for increased donor material and the problems associated with autogenous bone procurement mentioned above.⁴ Allogenic bone is usually processed as a freeze-dried graft or as a demineralized bone matrix (DBM). The former is usually placed with autogenous grafts due to the lack of osteogenic and osteoinductive capabilities.¹ Xenografts are more available in greater supply than allografts and have larger sizes. Most of the xenografts that are currently used have porcine and bovine origins, because of their similarity to the human bone regarding chemical composition (mainly carbonated hydroxyapatite and Type I collagen) and structure. Also, the interest in natural coral exoskeletons has been increasing.¹ Synthetic grafts are the other alternatives to the BGMs. The advantages of these materials include reduced morbidity of harvesting autogenous and/or allograft bone, increased availability, and decreased anesthetic/operative time and associated costs. Commercial materials differ in the tailoring of their size, form, osteoconductivity, osteoinductivity, and resorption kinetics.⁵ Despite the increase in the number of procedures that require bone grafts, there has not been an ideal bone graft substitute.⁶

Due to the radiopacity of graft materials, it is possible to radiologically detect the form and voids within the material. Enough radiopacity in order to be distinguished from the surrounding anatomic structures is a desirable property for dental graft materials as well as all biomaterials. A number of studies focusing on the radiopacity of dental materials including direct restorative materials, cavity liners, denture base materials, elastomeric impression materials, endodontic sealers, posts and retrograde materials, adhesive systems, etc., have been reported.⁷

As a general rule, densitometers are used for reading optical densities on radiographic films, in accordance with the recommendations of the American Dental Association.⁸ In the transmission densitometer, the obtained optical density is a logarithmic measure of the ratio of

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Table 1: Bone graft materials evaluated in this study and their detailed characteristics

Materials	Manufacturer	Composition	Grain size
Osteobiol Mp3	Tecnoss, Italy	Cortico-cancellous porcine bone mix	0.6–1 mm
Osteobiol Gel 40	Tecnoss, Italy	Cortico-cancellous porcine bone mix	≤0.3 mm
Osteobiol Putty	Tecnoss, Italy	Cortico-cancellous porcine bone mix	≤0.3 mm
Maxxeus	Community Tissue Services, Ohio, USA	Allograft, Cortico-cancellous	0.5–1 mm
Allogenix (Putty)	Biomet, Microfixation, Irvine, USA	Allograft contains porous ceramic granules	0.5 mm
K-Phate	Merries International Inc., Taiwan	Constituted by an ideal mixture of biphasic calcium phosphate ceramic, 60% hydroxyapatite and 40% β -tricalcium phosphate	0.5–1 mm
Suprabone	BMT Calsis A.S, Ankara, Turkey	β -tricalcium phosphate	1–2 mm
Puros	Tutogen Medical GmbH, Germany	Allograft, Cortico-cancellous	0.25–1 mm
Raptos	Community Tissue Services, Dayton, USA	Allograft, Cortico-cancellous	0.5–1 mm
Poresorb	Lasak Ltd, Praha, Czech Republic	Ceramic based on $[\beta\text{-Ca}_3(\text{PO}_4)_2]$	0.3–0.6 mm
Kasios Tcp	Kasios, ZI La Croix, Launaguet, France	β -tricalcium phosphate	0.5–1 mm
Mineross	Osteotech, Eatontown, USA	Allograft, Cortico-cancellous	0.6–1.25 mm
Bego Oss	aap Biomaterials GmbH, Dieburg, Germany	1 cm ³ ceramic consists of 0.6–1.1 gm hydroxyapatite (pentacalcium hydroxide trisphosphate) on average depending on the porosity of the ceramic	0.5–1 mm
Grafton Dbm (Putty)	Osteotech, France	Demineralized human bone matrix	Not available
4Bone	MIS Implant Technologies Ltd., Israel	Calcium phosphate ceramic consisting of 60% hydroxyapatite and 40% beta-tricalcium phosphate	0.5–1 mm

transmitted to incident light through the film image.⁹ Radiopacity is usually expressed in terms of aluminum thickness and many researchers use aluminum stepwedges to compare the radiopacity of restorative materials under typical radiographic conditions.^{7,10}

The aim of the present study is to detect the radiopacity of commercially available BGMs in cadavers' mandibles to mimic the *in vivo* conditions and compare them with each other and bone tissue.

MATERIALS AND METHODS

This study evaluated the radiopacity of 15 BGMs that are commercially available. Their specifications are given in Table 1. Of the BGMs tested, six materials were allografts, three materials were xenografts, and the remaining six were synthetic grafts. Eight BGMs' grain size was higher than 0.6 mm and 4 BGMs' grain size was lower than 0.6 mm.

A 5 × 10 mm-sized cavity was prepared with implant drill in the cadaver mandible (Fig. 1). The BGMs were prepared according to manufacturer's instructions and placed into the cavity respectively. After each implementation, parallel technique was utilized using a dental X-ray machine (Evolution X 3000-2C, New Life Radiology Srl, Italy) at 70 kVp and 8 mA for 0.2 s with a 20 cm film–target distance. Size 2, Kodak D-speed dental films (Eastman Kodak) with a 7-step stepwedge (from 1 to 7 mm) were exposed (Fig. 2). Films were processed using an automatic processor (Extra-x Velopex, Medivance



Fig. 1: 5 × 10 mm-sized cavity in cadaver's right mandible

Instruments Limited, London, England) with fresh solution (Hacettepe, Ankara, Turkey) mixed according to the manufacturer's instructions. For each material, three films were exposed and three readings were taken from each area and the mean was calculated. After exposure, the cavity was washed with distilled water and dried until all particles were removed. The radiographic densities of each step of the stepwedge, BGMs, bone, and enamel were measured using a densitometer (Densonorm 21 i, Phamed, Sulzbach, Germany) with a 1 mm aperture (Fig. 3). A graph of the optical density values for the entire stepwedge was plotted with the following equation: $(y = -0.664 \ln(x) + 1.909, R^2 = 0.987)$ (Graph 1) and used

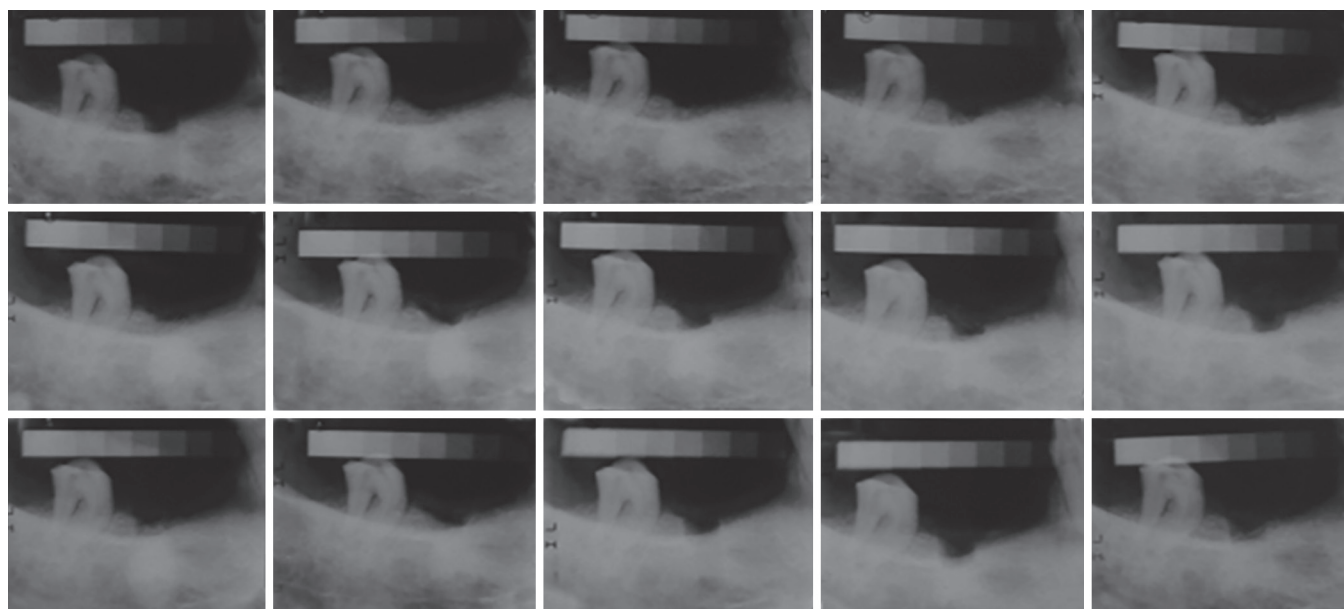
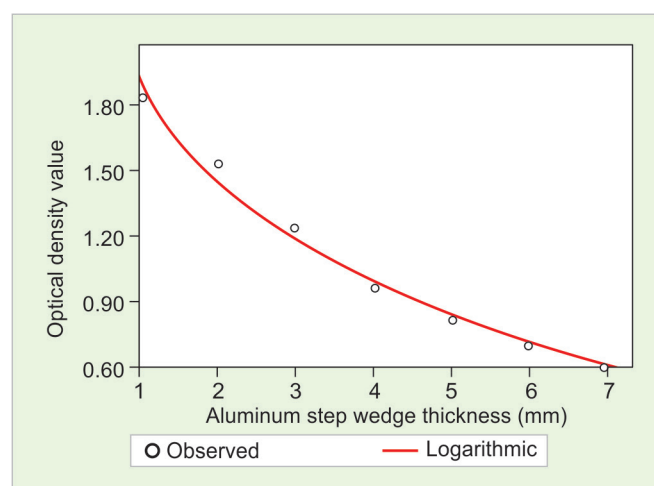


Fig. 2: Periapical radiographies of the cadaver's created cavity filled with BGMs, which were tested (upper line (from left to right): Grafton—Osteobiol Gel 40—Osteobiol Putty—Osteobiol MP3—Maxxeus middle line (from left to right): Kasios—Poresorb—4Bone—Raptos—Puros; lower line (from left to right): Bego Oss—K-Phate—Allogenix—Suprabone—Mineross)



Fig. 3: Transmission densitometer used in the present study



Graph 1: Optical density calibration curve

to determine the aluminum thickness equivalent values of the materials. The mean radiopacity values for each of the materials tested were compared using ANOVA and *post hoc* Tukey honest significant difference tests ($p < 0.05$).

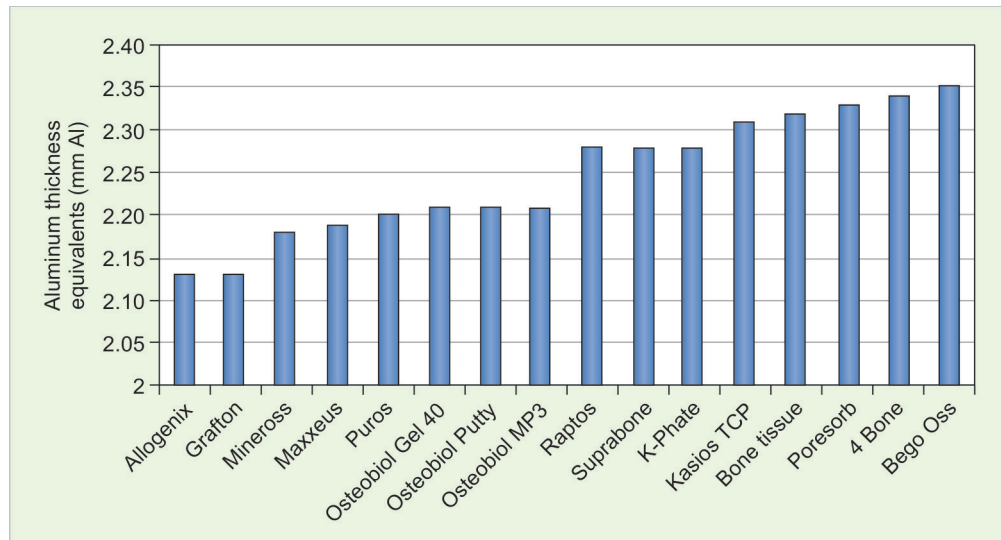
RESULTS

The transmission densitometry optical density values of BGMs varied from 0.51 (the most radiopaque) to 0.71 (the most radiolucent). The aluminum equivalent thicknesses of the BGMs ranged from 2.13 to 2.35 mm Al (Graph 2). Bego Oss (aap Biomaterials GmbH, Germany) exhibited the highest radiopacity of the materials tested, and Allogenix putty (Biomet, USA) exhibited the lowest (Table 2). The mandibular bone density was detected

as 2.32 mmAl. No significant differences were found among Kasios (Kasios, France), Poresorb (Lasak, Check Republic), 4Bone (Mis, Israel), Bego Oss, and mandibular bone tissue ($p \geq 0.05$) (Table 3). The other BGMs exhibited less radiopacity than bone tissue with a marked significance ($p \leq 0.05$).

DISCUSSION

In addition to BGMs' biological, physical, and mechanical properties, the radiopacity should be considered in selecting the most suitable material for specific clinical situations. There have been numerous histologic, histomorphometric, physicochemical experimental *in vivo* and *in vitro* studies in order to assess BGMs characteristics.



Graph 2: Aluminum equivalent values of tested BGMs and bone tissue

Also, radiographic evaluation of the BGMs has been carried out in various studies.

Verhoeven et al¹¹ carried out the densitometric measurements on standardized oblique lateral cephalometric radiographs of the onlay grafts implemented to severe mandibular atrophy patients for a 1-year period. While there is a decrease in the density of the upper cortex of graft material, no significant change was observed in the upper spongy part of the graft in the first 6-month period. An increase was detected in the radiographic density of the lower part of the spongy bone in the second 6-month period.

Üngör³ evaluated the radiographic density of the two forms of DBM (putty and powder) on panoramic radiographs after maxillary sinus floor augmentation procedure and no significant differences were detected between the materials.

The increase of radiopacity was investigated by Ajeesh et al¹² as a result of addition of nanoiron oxide to hydroxyapatite that has been widely used for a variety of bone filling and augmentation applications in dental and orthopedic field.

Bone mineral density measurements were also evaluated in numerous studies by dual-energy X-ray absorptiometry (DXA).^{13,14} The DXA is known as the most accurate clinical method for identifying those with low bone mineral density.^{15,16}

Some researchers compared the different donor bone types density with computed tomography (CT). Beckers et al¹⁷ showed that the iliac crest was the most consistently implantable donor site. In the study of Myoung et al,¹⁸ they evaluated the 120 bones from 20 Korean adults with CT. The cranial bone showed the highest cancellous bone density with statistical significance.

Table 2: Test results of BGMs used in the study

Tested materials	Mean optical density	Aluminum equivalent value (mm Al)	Standard deviation
Allogenix	0.71	2.13	±0.006
Grafton	0.71	2.13	±0.005
Mineross	0.66	2.18	±0.004
Maxxeus	0.65	2.19	±0.008
Puros	0.64	2.20	±0.006
Osteobiol Gel 40	0.63	2.21	±0.004
Osteobiol Putty	0.63	2.21	±0.004
Osteobiol MP3	0.63	2.21	±0.004
Raptos	0.57	2.28	±0.01
Suprabone	0.57	2.28	±0.007
K-Phate	0.57	2.28	±0.004
Kasios TCP	0.54	2.31	±0.006
Poresorb	0.53	2.33	±0.006
4Bone	0.52	2.34	±0.006
Bego Oss	0.51	2.35	±0.006

Dental materials are constantly reformulated and the desired goals are to make them radiopaque enough to enable a radiographical evaluation. Up to now, no published literature was found regarding the short-term radiopacity of BGMs after surgical procedure.

Pekkan et al¹⁹ investigated the radiopacity of six BGMs by comparing them with bovine mandibular cortical bone. Among the tested materials, Apatite–Wollastonite had the highest radiopacity with 3.681 mm Al that was the nearest density to bovine mandibular cortical bone. The least radiopacity was exhibited by Bio Oss with 1.925 mm Al. The common material used in both studies was Kasios TCP. The equivalent thickness was found in the study of Pekkan et al⁷ and in the present study, 2.912 mm Al, 2.31 mm Al respectively. The differences were attributed

Table 3: Double cross-check of BGMs used in this study according to radiopacity

	Allogenix	Grafton	Mineross	Maxxeus	Puros	Osteobiol Gel 40	Osteobiol Putty	Osteobiol MP3	Raptos	Suprabone	K-Phate	TCP	Poresorb	4Bone	Bego Oss
Allogenix	*														*
Grafton		*													*
Mineross			*												*
Maxxeus				*											*
Puros					*										*
Osteobiol Gel 40						*									*
Osteobiol Putty							*								*
Osteobiol MP3								*							*
Raptos									*						*
Suprabone										*					*
K-Phate											*				*
Kasios TCP												*			*
Poresorb													*		*
4Bone														*	*
Bego Oss															*

*p<0.05

to imaging conditions of each study while cadaver with soft tissue was used in this study.

This experimental study revealed that most of the tested BGMs showed less radiopacity than the bone tissue. Therefore, they are not recommended to be used in cases that have to be followed up radiographically in a short-term period postoperatively, as the cortical bone may mask the graft material when the defect is surrounded with the cortical bone.¹⁹

Contrary to other studies that deal with the radiopacity of dental materials, to the author's knowledge, this is the first study that evaluates comparative radiopacity of BGMs by simulating the oral environment conditions with the use of cadaver's mandible. This study was solely planned to ascertain the radiopacity of BGMs in the preliminary stage and compare them with each other. Further *in vivo* studies that reflect the clinical conditions will be designed in the following stages.

In the present study, majority of the materials lay below the bone tissue's radiopacity that would hamper the radiographic appearance when placed in the bone defect. Further studies should be conducted with commercially available BGMs to encourage their manufacturers to produce materials with more appropriate opacity levels.

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