Osseointegration of Superhydrophilic Implants Placed in Defect Grafted Bones

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Purpose: *Only limited information on the effect of implant surface hydrophilicity in conjunction with simultaneous bone augmentation is available. In this study, new bone growth around implants with a superhydrophilic modSLA (SLActive) and hydrophobic SLA (SLA) surface were compared in circumferential defects when grafted in conjunction with mineralized cancellous bone allograft (MCBA, maxgraft) or sintered bovine bone mineral (SBBM, cerabone).* ***Materials and Methods:*** *The osseointegration and bone formation in circumferential defects in minipig mandibles around Straumann Roxolid, Ø 3.3 mm, length 8 mm, either SLA or SLActive, were evaluated. Following implant placement, the 2-mm circumferential defects around the implants were filled with MCBA or SBBM. The distance from the implant shoulder to first bone-to-implant contact (f-BIC), percentage of bone-to-implant contact (BIC), and bone aggregate percentage (amount of new bone and remaining graft) within the defect area were evaluated after 8 weeks of healing.* ***Results:*** *In the SBBM group, lingual f-BIC and buccal BIC were significantly lower for SLA (mean –0.404 ± 0.579 mm for modSLA vs –1.191 ± 0.814 mm for SLA, P = .021, and mean 62.61% ± 9.49% for modSLA vs 34.67% ± 24.41% for SLA, P = .047, respectively). Bone aggregate percentage was significantly higher for modSLA vs SLA implants in SBBM (77.84% ± 6.93% vs 64.49% ± 13.12%, P = .045). The differences between implant surfaces in MCBA showed a similar trend but were less pronounced than in the SBBM group and did not reach a statistically significant level.* ***Conclusion:*** *The results suggest that implants with a superhydrophilic modSLA surface are more conducive to faster osseointegration even in conjunction with simultaneous bone grafting procedures.* INT J ORAL MAXILLOFAC IMPLANTS 2019;34:443–450. doi: 10.11607/jomi.7172

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Dental implants represent a well-established treatment modality for the prosthodontic rehabilitation of partially or fully edentulous patients. Insufficient bone volume of the alveolar ridge caused by bone resorption is a common clinical situation encountered during implant treatment. Different clinical strategies have evolved to proceed with implant treatment, augment missing bone volume, or proactively prevent the loss of bone volume after tooth extraction.[1] Short and narrow implants have recently emerged as a treatment modality in situations with restricted bone volume.[2] However, in the majority of conditions, ridge augmentation or preservation by guided bone regeneration (GBR) remains the method of choice.[3,4] Next to autologous bone, a vast variety of commercially available bone graft substitutes such as allografts,[5] xenografts,[6] and synthetic materials[7,8] are now well established and readily available for these procedures.

Besides the type of bone graft substitute, the clinical outcome of implant restorations involving GBR might also be influenced by the type of implant surface.[9] The influence of topographic and physicochemical surface properties on the osseointegrative potential of endosseous titanium dental implants is now well accepted.[10] Microroughened surfaces such as, eg, the large-grit

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sandblasted and acid-etched (SLA) implant surfaces have emerged over machined or macroroughened surfaces, as they result in superior bone-to-implant contact (BIC) and higher in vivo removal torque forces.[11,12] Modifications of the surface chemistry and reduction of the surface energy have further improved the osseointegration of these surfaces.[13] Compared with their hydrophobic counterparts, superhydrophilic modified SLA surfaces (modSLA, commercially available as SLActive) have, eg, been reported to stimulate the in vitro osteoblastic differentiation of preosteoblasts and to result in faster osseointegration as supported by various preclinical animal[14–17] and human histologic clinical studies.[18] Today, the superhydrophilic modSLA surface can be considered as the gold standard in dental implantology.

The effect of implant surface modifications on osseointegration in the absence of bone grafting has been well researched.[9–11] Furthermore, bone formation after bone grafting with different types of bone graft materials is well documented.[5–7] However, only very limited studies have systematically investigated the bone formation and osseointegration of dental implants in conjunction with bone grafting procedures and the influence of implant surface modification on these biologic processes. Dasmah et al[19] and Pinholt[20] have compared the effect of topographic implant surface modification on the osseointegration in augmented and nonaugmented bone. Specifically, Dasmah et al[19] have compared fluoridated sandblasted with machined surfaces, while Pinholt[20] have compared SLA with machined surfaces both in grafted and nongrafted bone and in autologous grafted bone, respectively. In both studies, the authors have reported superior osseointegration of the surface-modified implants compared with the machined implants. Philipp et al[21] compared the osseointegration of SLA and modSLA surfaces in grafted synthetic bone material. The authors reported no difference in BIC between the two surface types at 12 weeks after implantation, while at 26 weeks, higher BIC values were observed for modSLA compared with SLA surfaces.[21] No studies have so far systematically addressed the effect of hydrophilicity of SLA implant surfaces on the osseointegration and bone formation at an early stage in circumferential defects filled with bone graft materials. This report presents the results of a preclinical in vivo minipig study that compared the osseointegration and bone formation of hydrophobic SLA and superhydrophilic modSLA implant surfaces when placed in well-defined circumferential contained defects and simultaneously augmented with mineralized cancellous bone allograft (MCBA, maxgraft) or sintered bovine bone mineral (SBBM, cerabone) at 8 weeks after implantation.

MATERIALS AND METHODS

This study was approved by the Ethical Committee of the University of Lund (Sweden) (M-192-14) and conducted in accordance with ISO 10993-6 "Biological evaluation of medical devices – Part 6: Tests for local effects after implantation guideline and recommendations." This study conforms to the ARRIVE Guidelines.

The study included five female Göttingen Minipigs (Ellegaard), with a mean age of 20 months (19.5 to 21 months) at the time of surgery and a mean body weight of 34 kg. The animals were kept in groups of four or two, in standard boxes, for 1 week to adapt to the animal experimental conditions prior to surgery. They were fed a standard soft food diet (Special Diet Services [SDS], Witham, UK #801586). Prior to the surgical procedure, all animals were fasted overnight to prevent vomiting.

Surgical Procedure

All surgical procedures were performed under general anesthesia: 10 mL of ketamine (Ketalar Vet, Pfizer) mixed with 3 mL midazolam (Dormicum 5 mg/mL, Roche) was introduced via intramuscular injection. During surgery, 10 mL of ketamine was injected when needed, usually every 30 to 40 minutes, with 1.5 mL of midazolam if necessary. To reduce the dosage of the systemic anesthetic and to reduce bleeding during surgery and alleviate pain postsurgery, an additional local anesthetic (Xylocain Dental adrenalin 20 mg/mL + 12.5 mg/mL, Astra) was also used. Further analgesia was given if necessary when monitoring the animals during the healing phase. The animals were also treated with antibiotics for 7 days postsurgery (Streptocillin vet, 3 to 4 mL/pig i.m., Boehringer Ingelheim International).

Two surgical interventions were performed in each animal, under aseptic conditions in an operating suite dedicated to animal surgery: *(1)* tooth extraction and *(2)* defect creation and implant placement.

Tooth Extraction. The lower mandibular premolars (P2 to P4) and first molar (M1) were carefully removed bilaterally by means of a midcrestal incision and elevation of a full-thickness flap.

Implant Placement, Defect Creation, and Graft Placement. After allowing at least 3 months of healing post–tooth extraction, both sides of the mandibular alveolar ridge were exposed after crestal incision and reflection of the mucoperiosteal flap. Gentle grinding of the bone was performed under permanent cold saline cooling. The alveolar ridge was flattened using a Ø 2.3 mm round bur. An adapted Ø 2.8 mm pilot drill was used to create three implantation sites per half mandible by means of a "step" collar 4 mm from the drill apex (Fig 1a). Implants were placed 8 mm deep,

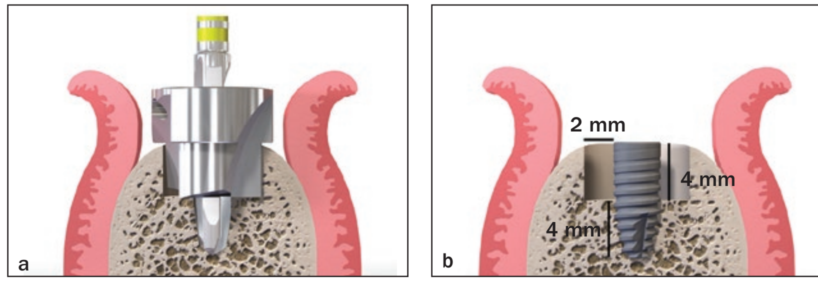

Fig 1 *(a)* Creation of circumferential defects using an adapted Ø 2.8 mm pilot drill with a step collar 4 mm from the drill apex, simultaneously creating the defect and implant site. *(b)* Straumann Bone Level Implant (Ø 3.3 mm) in situ in circumferential defect, with gap of 2 mm around each implant for grafting.

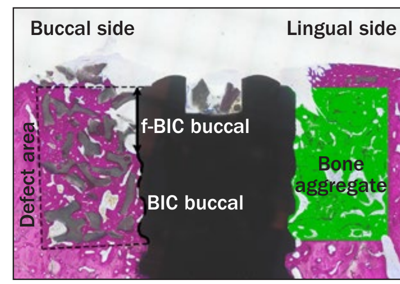

Fig 2 Schematic representation of areas and parameters of histomorphometric analysis. The defect area was defined as the gap of 2 mm around the implant by 4 mm down to the step. Bone aggregate and BIC are presented only for the defect area. f-BIC was measured as the distance from the implant shoulder to the first bone-to-implant contact *(black arrow)*. Bone aggregate was measured as the percentage of new bone plus remaining bone graft of the defect area *(green area)*. BIC was measured as the percentage of the implant in contact with bone *(black dotted line)* of the total implant surface in the defect area.

whereby the apical 4 mm was anchored in the bone and the coronal 4 mm was exposed to the circumferential defect (allowing a 2-mm gap around the coronal part of the implant once placed) (Fig 1b).

Each animal received three Bone Level Tapered (BLT) Roxolid SLActive implants with modSLA surface and three Bone Level Tapered (BLT) Roxolid SLA implants with SLA surface (both Ø 3.3 mm × 8 mm long) (Institut Straumann), which were inserted using the Loxim transfer piece, ratchet, and hexagonal screwdriver. A healing cap (closure screw) was inserted into each implant.

Following implant placement, the circumferential defects around the implants were grafted with mineralized cancellous bone allograft (MCBA, maxgraft 0.5–2 mm cancellous granules, 2 cc; botiss biomaterials, processed from human donor bone), sintered bovine bone mineral (SBBM, cerabone 0.5–1 mm granules, 2 cc; botiss biomaterials, a natural bovine bone substitute), or natural bovine bone mineral (NBBM, Bio-Oss, Geistlich Pharma). Each implant type defect was grafted either with allograft or either type of xenograft in a randomized fashion (n = 5 per group) resulting in four experimental groups: group 1: SLA, SBBM; group 2: modSLA, SBBM; group 3: SLA, MCBA; and group 4: modSLA, MCBA. Only the results for the MCBA and SBBM groups will be reported here; the comparison of the NBBM and SBBM groups will be the subject of a separate paper.

Augmented defects were covered with a porcine pericardium membrane (Jason, botiss biomaterials) and sutured using an interrupted horizontal mattress technique (Vicryl 4-0, FS2; Ethicon).

Termination

The five animals were sacrificed at 8 weeks after graft placement by means of an intracardiac injection of a 20% solution of pentobarbital (Pentobarbital-natrium, Apoteket, 60 mg/mL) to induce a cardiac arrest.

Histologic Processing. Block resection of the implant sites (mandible) was performed using an oscillating autopsy saw, such that the soft tissue remained intact. The hemi-mandibles were then fixed by immersion in formalin (formaldehyde 4% solution) for a minimum of 2 weeks prior to histologic processing. The bone samples were then dehydrated by ascending grades of alcohol and xylene. Methyl methacrylate was used for infiltrating, embedding, and nondecalcified sectioning. Each target site (ie, implant embedded in the grafted defect) was cut in a buccolingual direction. For microscopic evaluation, a 500-µm section was obtained, ground to a final thickness of 30 to 50 µm, and stained with paragon stain (toluidine blue and basic fuchsin).

Quantitative Histomorphometry. Histomorphometric measurements were performed on central buccolingual sections within the defect area (coronal part of the implant) (Fig 2). The distance from the implant shoulder to the first bone-to-implant contact (f-BIC) and the percentage of BIC were calculated at the buccal and lingual aspects. A bone aggregate percentage in the defect area was calculated, consisting of the combined percentage of the new bone and the remaining graft material.

Statistical Evaluation. Descriptive statistics were performed for implant type and implant type by biomaterial. A paired *t* test and Wilcoxon signed rank test

Table 1 Adjusted Comparisons Between Implant Type and Measured Outcomes (Multiple Regression Analysis)

		Regression parameters[a]		Adjusted parameters[a]		
Outcome/factor	Value	Regression estimate	SE	Adjusted mean	95% CI	*P* value[b]
fBIC[c] (μm)						
Intercept	I	12.85	2.13			
Graft material	MCBA Groups 3 and 4	–6.86	2.01	–2,430.16	–2,622.46 to –1,732.7	.00039
	SBBM Groups 1 and 2	0		–869.23	–1,594.74 to 30.73	
Position	Anterior	5.29	2.59	–1,025.05	–1,801.50 to 20.88	.1035
	Middle	4.73	2.37	–1,183.84	–1,800.56 to –343.60	.1115
	Posterior	0		–2,410.47	–2,673.63 to –1,583.2	
Implant	SLA Groups 1 and 3	–4.80	1.94	–1,857.49	–2,608.11 to –1,577.7	.0258
	modSLA Groups 2 and 4	0		–976.70	–1,736.09 to –92.46	
Percent BIC of circumference–defect area[c] (%)						
Intercept	I	13.89	2.04			
Graft material	MCBA Groups 3 and 4	–8.18	1.92	22.84	13.03 to 26.81	.0007
	SBBM Groups 1 and 2	0		58.95	38.81 to 62.93	
Position	Anterior	1.89	2.48	29.49	23.87 to 58.79	.6646
	Middle	4.07	2.27	46.94	26.95 to 59.93	.1577
	Posterior	0		26.59	19.98 to 39.97	
Implant	SLA Groups 1 and 3	–3.00	1.86	26.71	22.17 to 39.03	.1272
	modSLA Groups 2 and 4	0		39.49	26.75 to 59.02	
Percent new bone and graft material of total defect area (bone aggregate) (%)						
Intercept	I	15.05	1.68			
Graft material	MCBA Groups 3 and 4	–9.04	1.59	44.65	36.32 to 52.80	< .0001
	SBBM Groups 1 and 2	0		72.68	64.54 to 81.33	
Position	Anterior	3.18	2.05	60.26	53.01 to 70.83	.2364
	Middle	3.05	1.87	60.10	53.32 to 68.10	.2088
	Posterior	0		52.87	41.56 to 60.10	
Implant	SLA Groups 1 and 3	–4.40	1.54	52.75	44.61 to 57.45	.0118
	modSLA Groups 2 and 4	0		64.86	56.28 to 72.72	

[a]Adjustment done for plane of measurement, position, and graft material as fixed effects and animal as random effects.
[b]Dunnett-Hsu test.
[c]The buccal and lingual measurements were averaged for this outcome.

were used to assess differences in outcomes between the two implant types. Furthermore, adjusted comparisons or adjusted associations between surface types and new bone and osseointegration (multiple regression analysis) were done to evaluate the influence of the surface type irrespective of the graft material and implant position. Table 1 shows the results from the adjusted comparisons of the surface type for the different outcomes.

Because of the small sample size, the adjusted comparisons were performed via mixed regression models using the Brunner-Langer nonparametric method.[22] The associations between implant types and the outcomes were adjusted by the effects of the position of the implant in the mandible, plane of measurement (when applicable), and biomaterial (included in the model as fixed effects). The effect of the animals was introduced in the model as a random effect. The Dunnett-Hsu adjustment[23] was used to adjust the *P* values in the case of multiple comparisons. Before calculating the models, the global comparisons of the effects of the surface type and biomaterial were examined first, and then the calculated effects cited earlier were performed.

RESULTS

All animals recovered predictably from the surgical procedures, and subsequent healing was unremarkable. No surgical, perioperative, or postoperative complications were noted, and no peri-implant inflammation was present on examination of the mandibles at termination.

Table 2 Overview of Experimental Results and Statistical Comparison by Means of a Student *t* Test

	SBBM		MCBA		
Outcome	**modSLA (Group 2)**	**SLA (Group 1)**	**modSLA (Group 4)**	**SLA (Group 3)**	***P* values (comparison of biomaterials within implant types)**
f-BIC lingual (mm)	−0.405 ± 0.579	−1.191 ± 0.814	−1.694 ± 1.749	−2.071 ± 0.581	Group 2 vs group 4 = .2184
	P = .021		*P* = .578		Group 1 vs group 3 = .1398
f-BIC buccal (mm)	−0.343 ± 0.609	−1.535 ± 1.344	−1.354 ± 1.259	−2.802 ± 0.428	Group 2 vs group 4 = .1242
	P = .074		*P* = .060		Group 1 vs group 3 = .0676
BIC buccal (%)	62.61 ± 9.49	34.67 ± 24.41	34.56 ± 27.07	14.51 ± 6.90	Group 2 vs group 4 = .0890
	P = .047		*P* = .147		Group 1 vs group 3 = .0907
BIC lingual (%)	63.16 ± 10.19	52.71 ± 24.71	21.44 ± 19.43	23.84 ± 10.65	Group 2 vs group 4 = .0129
	P = .452		*P* = .741		Group 1 vs group 3 = .0416
Bone aggregate (%)	77.84 ± 6.93	64.49 ± 13.12	50.92 ± 16.16	38.89 ± 5.45	Group 2 vs group 4 = .0397
	P = .045		*P* = .140		Group 1 vs group 3 = .0025

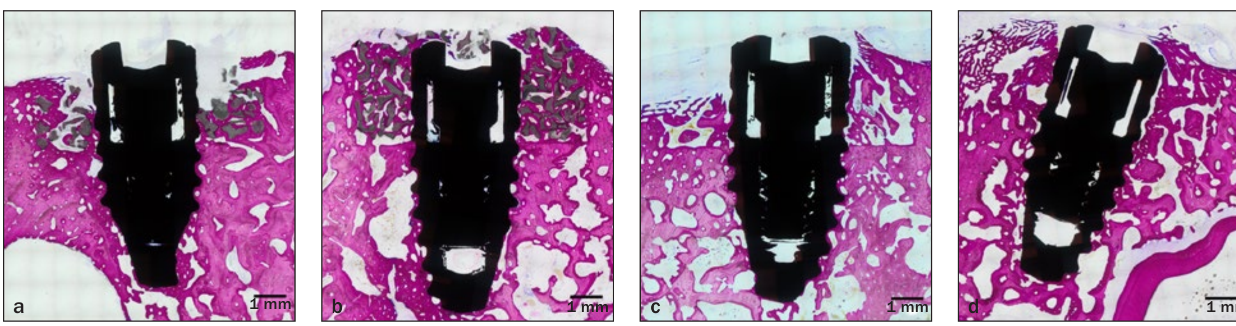

Fig 3 Representative micrographs of histologic sections in buccolingual direction. *(a)* SLA and *(b)* modSLA in combination with SBBM. *(c)* SLA and *(d)* modSLA in combination with MCBA.

Histologic and Histomorphometric Analysis

All implants were well osseointegrated after 8 weeks. An overview of the results including statistical comparisons is given in Tables 1 and 2. Within the SBBM group, dense bone was observed around both implant types (groups 1 and 2), and the bone substitute material was well integrated in newly formed bone in the defect (Figs 3a and 3b). Within the MCBA group (groups 3 and 4), however, the bone surrounding the implants appeared less dense, with large trabecular spaces (Figs 3c and 3d). Irrespective of the graft material, the modSLA surfaces (groups 2 and 4) appeared to better promote osseointegration and new bone formation compared with the hydrophobic SLA surface (groups 1 and 3) (Figs 3b and 3d).

After 8 weeks of healing with SBBM as the graft material, the distance from the implant shoulder to the first BIC on the buccal aspect (f-BIC buccal) was lower for modSLA implants (group 2) compared with SLA implants (group 1) (mean −0.343 ± 0.609 mm for modSLA vs −1.535 ± 1.344 mm for SLA, *P* = .074; Fig 4a). Similar behavior was observed in the MCBA group (mean −1.354 ± 1.259 mm for modSLA [group 4] vs −2.802 ± 0.428 mm for SLA, *P* = .060 [group 3]; Fig 4a). At the lingual aspect, f-BIC was significantly lower for SLA implants (group 1) compared with modSLA implants (group 2) in the SBBM group (mean −0.405 ± 0.579 mm for modSLA and −1.191 ± 0.814 mm for SLA, *P* = .021; Fig 4b), while lingual f-BIC values of both implant types in the MCBA group were comparable but followed the same trend (mean −1.694 ± 1.749 mm for modSLA [group 4] and −2.071 ± 0.581 mm for SLA [group 3], *P* = .578, respectively).

In the SBBM group, the mean BIC percentage in the circumferential defect area was greater around modSLA (group 2) compared with SLA implants (group 1), with a significant difference at the buccal aspect (mean 62.61% ± 9.49% for modSLA vs 34.67% ± 24.41% for SLA, *P* = .047). The same trend was observed for the lingual aspect with a mean BIC of 63.16% ± 10.19% for modSLA (group 2) vs 52.71% ± 24.71% for SLA (group 1). Compared with SBBM augmented implants, mean BIC values around MCBA augmented implants were lower for both implant type groups. While values at the lingual aspect were comparable (21.44% ± 19.43% for modSLA [group 4] vs 23.84% ± 10.65% for SLA [group 3]), the BIC values at the buccal aspect were higher for the modSLA group (34.56% ± 27.07% for modSLA [group 4] vs 14.51% ± 6.90% for SLA [group 3]) (Figs 4c and 4d).

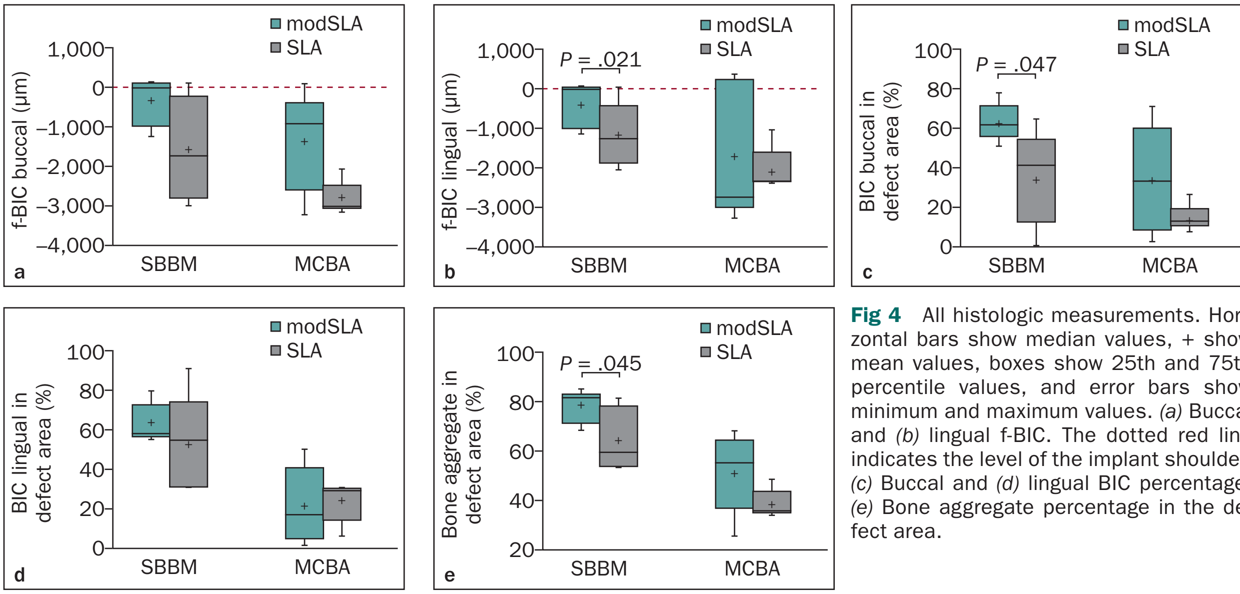

Fig 4 All histologic measurements. Horizontal bars show median values, + show mean values, boxes show 25th and 75th percentile values, and error bars show minimum and maximum values. *(a)* Buccal and *(b)* lingual f-BIC. The dotted red line indicates the level of the implant shoulder. *(c)* Buccal and *(d)* lingual BIC percentage. *(e)* Bone aggregate percentage in the defect area.

After 8 weeks of healing, the sum of newly formed bone and remaining graft material in the defect area (bone aggregate percentage) for the SBBM augmented group was significantly higher for modSLA implants (group 2) compared with SLA implants (group 1) (77.84% ± 6.93% vs 64.49% ± 13.12%, *P* = .045; Fig 4e). Compared with the SBBM group, the corresponding values in the MCBA group were lower, but the same trend between modSLA and SLA implants could be observed within the MCBA augmented group (50.92% ± 16.16% for modSLA [group 4] vs 38.89% ± 5.45% for SLA [group 3]; Fig 4e).

The adjusted associations between the measured outcomes (f-BIC, BIC, and bone aggregate) and implant types (modSLA and SLA) irrespective of graft material and position are shown in Table 1. The f-BIC adjusted mean for the SLA (groups 1 and 3) (–1.857 mm) is significantly lower than for the modSLA (–0.977 mm) surface (groups 2 and 4) (Dunnett-Hsu test, *P* = .026). Higher adjusted mean values for BIC were calculated for the modSLA (groups 2 and 4) (39.49%) compared with SLA (groups 1 and 3) (26.71%), although the difference was not significant (Dunnett-Hsu test, *P* = .127). A significantly higher adjusted bone aggregate was calculated for the modSLA (groups 2 and 4) (47.61%) compared with SLA (40.01%) (groups 1 and 3) (Dunnett-Hsu test, *P* = .012). The outcomes of this multiple regression analysis confirmed the trends observed in the paired analysis (Table 2).

DISCUSSION

This study assessed the osseointegration and new bone formation around microrough titanium implants placed in circumferential defects as a function of surface hydrophilicity. Specifically, from the comparison of the hydrophobic SLA and superhydrophilic modSLA implants, three main general observations were obtained: Compared with SLA implants (groups 1 and 3), modSLA implants (groups 2 and 4) generally resulted in *(1)* higher BIC irrespective of the graft material used, *(2)* lower distance from the implant shoulder to the f-BIC, and *(3)* higher bone aggregate (remaining graft and newly formed bone) around the implant.

Without specific precautions, titanium surfaces tend to quickly absorb hydrocarbons from the environment, which decreases their surface energy.[24] In combination with microrough surfaces, such as the SLA surfaces, this decreased surface energy results in hydrophobic and water-repellent implant surfaces.[25] One possibility to avoid surface contamination of titanium implants is their production under nitrogen atmosphere and constant storage in isotonic saline solution. This principle, which is used for the manufacturing of the modSLA implants, preserves the native superhydrophilic characteristics of the implant surface.[24] The effects of different surface energy and wettability of SLA and modSLA surfaces on bone formation upon endosseous implantation, ie, placement in nonaugmented bone, have been extensively studied. Bornstein et al have shown that modSLA surfaces show faster osseointegration and bone apposition compared with their hydrophobic counterparts SLA.[26] Results from in vitro research suggest that this faster osseointegration might be related to the stimulation of various biologic factors and processes associated with bone formation. Specifically, the modSLA surface has been shown to stimulate upregulation of osteogenic markers and growth factors such as runt-related transcription factor 2 (RUNX2), bone sialoprotein (BSP), secreted phosphoprotein 1 (SPP1), or vascular endothelial growth.[27–30] It has furthermore recently been suggested that primary human osteoblasts might be stimulated indirectly through the activation of the blood coagulation by the hydrophilic modSLA surface.[31] Interestingly, the increased osseointegrative potential of modSLA surfaces reported in the literature could be observed as well in this study in the presence of bone substitutes such as MCBA or SBBM. Furthermore, the higher BIC values of the modSLA surfaces in groups 2 and 4 correlated to some extent with higher f-BIC values and higher bone aggregate values.

Bone formation around dental implants has been described as a combination of distance osteogenesis, ie, bone formation starting from the borders of the defect and contact osteogenesis/osteoconduction, ie, bone formation on the surface of the implant as a result of osteogenic cells that migrate along the implant surface to form de novo bone. Assuming that in the current model and chosen defect type, contact osteogenesis might be the predominant mechanism for implant osseointegration, the higher BIC, lower f-BIC, and higher bone aggregate values observed around modSLA surfaces in experimental groups 2 and 4 might be related to a more pronounced contact osteogenesis of the modSLA surface. In the present study, the SBBM and MCBA materials might have contributed to the stabilization of the blood coagulum and supported the invasion and access of osteoprogenitor cells to the implant surface. Both processes have been described as important underlying mechanisms for the faster osseointegration of the modSLA surface.[16]

In this study, faster osseointegration and bone formation associated with modSLA surfaces was mainly observed in combination with SBBM (group 2). The differences between the two surface types were less pronounced in the MCBA group. However, differences in this group were less pronounced and did not reach statistically significant levels. Furthermore, bone formation in general was less pronounced in the MCBA group. These findings can be put into context with histologic studies from the literature that compare bone formation of other but similar allogeneic and xenogeneic materials. Lee et al have, eg, compared deproteinized bovine bone mineral with two types of allografts,[32] ie, irradiated cancellous and solvent-dehydrated allograft in a human histologic study at 4 to 6 months after implantation in extraction sockets. In accordance with the findings in this report, the authors have reported higher bone formation in the xenogeneic material and higher amounts of residual graft compared with the allogeneic materials and have attributed this to the osteoconductive properties of the xenogeneic material used in their study. In a different setting, Froum et al[33] compared bone formation of a mineralized cancellous allograft with inorganic bovine bone in a split-mouth design 26 to 32 weeks after bilateral sinus augmentation procedures in humans. The authors reported significantly higher bone formation in the allograft group compared with the xenograft group, while the xenograft group showed much higher residual bone graft material. Similar but less pronounced differences were reported as well by Schmitt et al, who compared bone formation as part of sinus augmentation with inorganic bovine bone mineral or mineralized cancellous bone allograft in a human histology setting 5 months after implantation.[34] The lower bone formation of the MCBA (groups 3 and 4) compared with the SBBM group (groups 1 and 2) observed in this study correlates to the findings of Lee et al[32]; however, it remains controversial. Inferiority of the MCBA material might be associated, eg, with the species dissimilarities between the human origin and the porcine host system used in the present study. Other possible reasons for the variation in performance between different allograft and xenogeneic materials might be related to differences in particle size and resorption characteristics.

While this study focused primarily on bone formation around different implant surfaces in the presence of bone graft substitutes, the study did not evaluate the level of bone formation around these implants in the absence of bone graft as a control group. Future studies assessing the level of bone formation around the different implant surfaces in empty circumferential defects might serve as a valuable control group to compare the experimental results presented in this study more objectively.

CONCLUSIONS

This study evaluated the extent of new bone growth around implants with hydrophobic SLA and superhydrophilic modSLA surfaces placed in circumferential defects with cancellous mineralized bone allograft or sintered bovine bone mineral. The amount and density of bone was greater around modSLA implants compared with SLA implants. The greater osseointegration at 8 weeks suggests that the use of modSLA implants is conducive to faster osseointegration in a guided bone regeneration setting, especially when the properties of modSLA and SBBM (eg, hydrophilicity, microporosity, promotion of early osteogenic differentiation) are combined. Compared with the MCBA group, bone formation as expressed by the bone aggregate was more pronounced in the SBBM group.

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