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The S2k-LL – Indications for the use of bone substitute materials in implant dentistry (083–009): the scientific quintessence

Summary: The replacement of missing teeth after unavoidable tooth loss is a core competence in dentistry. In addition to the obvious rehabilitation of the masticatory function and esthetics, there are increasingly more medical considerations that might warrant the replacement of missing teeth.
However, the prospective implant site is often compromised by defects of the alveolar process which are triggered by tooth loss or which develop after extraction. The preservation and, if necessary, the regeneration of the alveolar process thus play a major role in daily clinical practice. Various biomaterials are available to the dental practitioner besides autologous bone grafts. The following questions were addressed in the guideline "Implantological indications for the use of bone substitute materials" of the DGI and DGZMK:
1. which are the indications for bone augmentation, 2. which materials are available, 3. which techniques are recommended?
The key scientific statements of the guideline are summarized below. The literature references are therefore adapted to this format. The complete details and background are found in the guideline.

Keywords: tooth loss; bone augmentation; jaw atrophy; bone grafts; bone substitutes

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Type of defect	Single-tooth gap	Extended edentulous space, free-end gap	Edentulous jaw
1/4	Dehiscence defect, self-limiting	Multiple dehiscence defects, self-limiting	Multiple dehiscence defects, self-limiting
2/4	Horizontal defect, not self-limiting, augmentation required outside the "skeletal envelope"	Horizontal defect, not self-limiting, augmentation required outside the "skeletal envelope"	Sharp-edged alveolar ridge
3/4	Combined defect with horizontal and vertical bone deficits	Combined defect with horizontal and vertical bone deficits	Sharp-edged alveolar ridge with vertical bone deficit (Class IV according to Cawood)
4/4	Continuous defect	Pure vertical defect	Complete alveolar ridge atrophy (class V and VI according to Cawood)

Table 1 ITI classification of alveolar ridge defects according to Terheyden (Cordaro L 2014; Terheyden 2010).

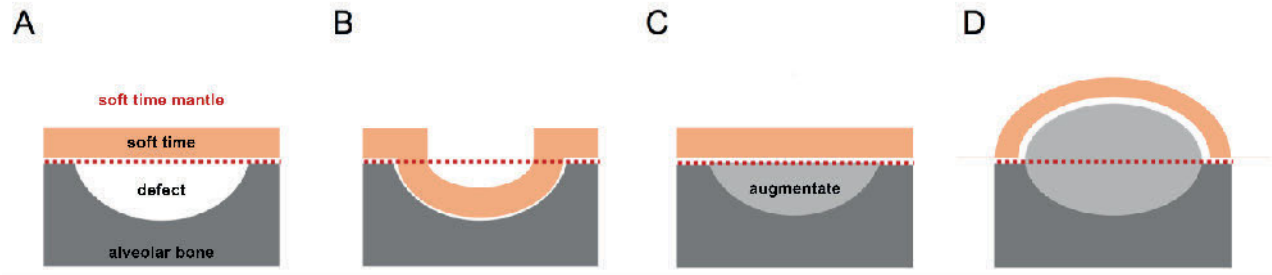


Figure 1 Schematic representation of the bone shape, the soft tissue coat and an augmentation inside and outside of the soft tissue coat. The representation applies to horizontal, vertical and combined alveolar ridge defects. The soft tissue coat (red line) describes the natural dimension of the alveolar ridge **(A)**. If such a defect is not augmented, the soft tissue prolapses and the bone shape is altered **(B)**. A distinction is made between augmentations inside **(C)** and outside **(D)** the soft tissue coat.

1. Biological basis

1.1 Defect biology

For reliable and lasting implant placement, the alveolar process must have sufficient dimensions. Among other factors, natural resorption, periodontitis and defects resulting from tooth extraction can be causes of hard and soft tissue defects of the alveolar process. Osteoblast activity is at its highest in the apical region during the first 4 weeks after tooth extraction, after which, it shifts toward the crestal region. In this context, resorption processes also take place [1].

It is important to note that bone resorption also results in soft tissue reduction. In this regard, the soft tissue coat plays an important role in the regeneration of existing bone defects. Although there is widespread clinical acknowledgement of this problem, the evidence on this topic remains scarce. A special emphasis pertaining to this topic was applied within the framework of this guideline.

The osseous regeneration of alveolar process defects is even more difficult if an intrusion of soft tissue has occurred. This effect can be counteracted by performing ridge preservation (filling the empty alveolar socket with a suitable material). The ITI classification [2, 3] exemplifies this clinical understanding (Table 1, Figure 1).

The biological regeneration potential consequently depends directly on the quantity of the delimiting bone and the surrounding soft tissue. Defect geometries which have extensive osseous delimitation have higher regeneration potential [2, 3].

Quintessence from the guideline

The following classification concerning the regeneration potential of a clinical situation can be derived:

- procedures reconstructing defects of the alveolar ridge and sinus lifting: high biological regeneration capacity,
- lateral augmentation: medium biological regeneration capacity,
- combined lateral and vertical augmentation: low biological regeneration capacity.

1.2 The medical history of the patient

The literature search revealed a paucity of data addressing the question of the extent to which pre-existing medical conditions can affect augmentation success.

There are indications for an increased complication rate and a lower

Type of material	Origin	Company	Product	Resorbable	Area of application
Allogeneic	Human bone matrix	Argon Dental	OsteoGraft® DBM	X	IM/PA/SA/GA/DS/AT
			OsteoGraft® CortiFlex®	X	IM/PA/SA/GA/DS/AT
			OsteoGraft® Femur Span	X	IM/PA/SA/GA/DS/AT
			OsteoGraft® Cortical Granula	X	IM/PA/SA/GA/DS/AT
			OsteoGraft® Spongiosa Granula	X	IM/PA/SA/GA/DS/AT
			OsteoGraft® J & CGrafts	X	IM/PA/SA/GA/DS/AT
			OsteoGraft® Osillium & Spongiosa Grafts	X	IM/PA/SA/GA/DS/AT
		Straumann (botiss)	Human-Spongiosa CHB Knochenring	X	IM/GA/DS
			Human-Spongiosa CHB Granulat spongiös	X	IM/PA/SA/GA/DS/AT
			Human-Spongiosa CHB Block	X	IM/GA/DS
			maxgraft® cortico	X	IM/GA/DS
			maxgraft® bonering	X	IM/GA/DS
			maxgraft® Granulat spongiös	X	IM/PA/SA/GA/DS/AT
			maxgraft® Granulat cortico-spongiös	X	IM/PA/SA/GA/DS/AT
			maxgraft® Block	X	IM/GA/DS
			maxgraft® bonebuilder	X	IM/GA/DS
		Zimmer Biomet	Puros® Allograft Block	X	IM/GA/DS
			Puros® Allograft Patienten individueller Block	X	IM/GA/DS
			Puros® Allograft Spongiosa Partikel	X	IM/PA/SA/GA/DS/AT
Xenogeneic	Equine	American Dental Systems	OsteoBiol® SP-Block (Bone Splitting/Spread.)	X	GA
		Mectron	BIO-GEN® Spongy		IM/PA/SA/GA/DS/AT
			BIO-GEN® Cortical		IM/PA/SA/GA/DS/AT
			BIO-GEN® Mix		IM/PA/SA/GA/DS/AT
			BIO-GEN® Putty		AT
	Porcine	American Dental Systems	OsteoBiol® Gen-Os	X	IM/PA/SA/GA/DS
			OsteoBiol® Apatos (Mix)		IM/PA/SA/GA/DS/AT
			OsteoBiol® mp3	X	IM/PA/SA/GA/DS/AT
			OsteoBiol® GTO®	X	IM/PA/SA/GA/DS/AT
			OsteoBiol® Putty	X	IM/PA/GA
			OsteoBiol® SP-Block (Bone Splitting/Spread.)	X	GA
			OsteoBiol® Bone Lamina Soft (Barrier)	X	IM/GA/DS
		CAMLOG	MinerOss® XP	X	IM/PA/SA/GA/DS/AT
		Champions-Implants	Matri™ Bone	X	IM/PA/SA/GA/DS/AT
			CollaWin!	X	IM/PA/SA/GA/DS/AT
		Curasan (Vertrieb: mds)	CERASORB® Foam	X	IM/SA/GA/DS/AT
		Dentsply Sirona	Symbios® Xenograft-Granulat	X	IM/PA/SA/GA/DS/AT
		Geistlich Biomaterials	Geistlich Bio-Oss® COLLAGEN	X	IM/PA/SA/GA/DS/AT
		Hess Medizintechnik	Geistlich Bio-Oss® COLLAGEN	X	IM/PA/SA/GA/DS/AT
		REGEDENT	The Graft		IM/PA/SA/GA/DS/AT
			OSSIX® VOLUMAX	X	IM/GA/DS
			OSSIX® Bone	X	IM/PA/SA/GA/DS/AT
		Straumann (botiss)	collacone® max	X	IM/AT
		Thommen Medical	The Graft		IM/PA/SA/GA/DS/AT
			OSSIX® Bone		IM/PA/SA/GA/DS/AT
	Bovine	BEGO Implant Systems	BEGO OSS		IM/PA/SA/GA/DS/AT
		BioHorizons (CAMLOG Dtl.)	MinerOss®-X	X	IM/PA/SA/GA/DS/AT
		Bioimplon	Hypro-Oss®	X	IM/PA/SA/GA/DS/AT
		CAMLOG	MinerOss® X	X	IM/PA/SA/GA/DS/AT
			MinerOss® X Collagen	X	IM/PA/SA/GA/DS/AT
		Dentegris Deutschland	CompactBone B	X	IM/PA/SA/GA/DS/AT
		Geistlich Biomaterials	Geistlich Bio-Oss® Spongiosa Granulat	X	IM/PA/SA/GA/DS/AT
			Geistlich Bio-Oss® Spongiosa Block	X	IM/SA/GA/DS
			Geistlich Bio-Oss® COLLAGEN	X	IM/PA/SA/GA/DS/AT
			Geistlich Bio-OssPen® Granulat	X	IM/PA/SA/GA/DS/AT
		Henry Schein	NuOss® Granulat	X	IM/PA/SA/GA/DS/AT

Table 2 Overview of the marketed augmentation materials in dentistry and oral and maxillofacial surgery. Status: April 2019. From: Yearbook of Implantology 2019, OEMUS MEDIA AG, Leipzig. Area of application: implantology (IM), periodontology (PA), sinus floor augmentation (SA), general augmentation (GA), defect surgery (DS), alveolar treatment (AT).

Type of material	Origin	Company	Product	Resorbable	Area of application
		Hess Medizintechnik	Geistlich Bio-Oss® Spongiosa Granulat	X	IM/PA/SA/GA/DS/AT
			Geistlich Bio-Oss® Spongiosa Block	X	IM/SA/GA/DS
			Geistlich Bio-Oss® COLLAGEN	X	IM/PA/SA/GA/DS/AT
			Geistlich Bio-OssPen® Granulat	X	IM/PA/SA/GA/DS/AT
		Nobel Biocare	creos xenogain	X	IM/PA/SA/GA/DS/AT
		OT medical	BioVin® Bovine Bone	X	IM/PA/SA/GA/DS/AT
		Septodont	R.T.R. Kegel	X	IM/PA/SA/GA/DS/AT
		Straumann (botiss)	cerabone®		IM/PA/SA/GA/DS/AT
		Zimmer Biomet	Endobon® Xenograft Granulat		IM/PA/SA/GA/DS/AT
			CopiOs® Xenograft Spongiosa Partikel	X	IM/PA/SA/GA/DS/AT
	plant-based	Dentsply Sirona	Frios® Algipore®	X	IM/PA/SA/GA/DS/AT
			Symbios® Biphasisches KAM	X	IM/PA/SA/GA/DS/AT
		Gebr. Martin/KLS Martin	Martrix	X	IM/PA/SA/GA/DS/AT
		SIC invent	SIC nature graft	X	IM/PA/SA/GA/DS/AT
Synthetic	HA/Collagen/Glycosaminoglycans	ACTEON Germany	BIOSTITE	X	IM/PA/SA/GA/DS
	Sodium hyaluronate	Argon Dental	OsteoGel® Hyaluron	X	IM/PA/SA/GA/DS/AT
	BCP	BEGO Implant Systems	BEGO OSS S	X	IM/PA/SA/GA/DS/AT
	β-TCP	Bicon	SynthoGraft™	X	IM/PA/SA/GA/DS/AT
	BCP	Champions-Implants	Matri™ Bone	X	IM/PA/SA/GA/DS/AT
	Kollagen		CollaWin!	X	IM/PA/SA/GA/DS/AT
	β-TCP	curasan (Vertrieb: mds)	CERASORB® Classic	X	IM/SA/GA/DS/AT
	β-TCP		CERASORB® M	X	IM/SA/GA/DS/AT
	β-TCP		CERASORB® Perio	X	PA
	β-TCP		CERASORB® Plus	X	IM/SA/GA/DS/AT
	β-TCP		CERASORB® Paste	X	IM/PA/SA/GA/DS/AT
	β-TCP		CERASORB® Foam	X	IM/SA/GA/DS/AT
	β-TCP		CERASORB® Formteile	X	DC
	HA		Osbone®		IM/PA/SA/GA/DS/AT
	Calcium sulfate/β-TCP	Demedi-Dent	ethOss	X	IM/PA/SA/GA/DS/AT
	BCP	Dentegris Deutschland	CompactBone S	X	IM/PA/SA/GA/DS/AT
	Collagen	Dentium/iCT Europe	OSTEON™		IM/PA/SA/GA/DS/AT
	Collagen		OSTEON™ Sinus & Lifting		IM/PA/SA/GA/DS/AT
	Collagen		OSTEON II™		IM/PA/SA/GA/DS/AT
	Collagen		OSTEON II™ Sinus & Lifting		IM/PA/SA/GA/DS/AT
	BCP	Dr. Ihde Dental	Nanos®	X	IM/PA/SA/GA/DS/AT
	HA/SiO_2	Hager & Meisinger	NanoBone® | granulate	X	IM/PA/SA/GA/DS/AT
	HA/SiO_2		NanoBone® | block	X	IM/GA/DS
	HA/SiO_2		NanoBone® | QD	X	IM/PA/SA/GA/DS/AT
	BCP	Henry Schein	BONITmatrix®	X	IM/PA/SA/GA/DS/AT
	β-TCP	K.S.I. Bauer-Schraube	calc-i-oss™	X	IM/PA/SA/GA/DS/AT
	BCP		easy-graft®	X	IM/PA/SA/GA/DS/AT
	β-TCP	LASAK	PORESORB-TCP	X	IM/PA/SA/GA/DS/AT
	HA		OssaBase® -HA	X	IM/PA/SA/GA/DS/AT
	HA/BCS	MIS Implants Technologies	4MATRIX	X	IM/PA/SA/GA/DS/AT
	BCP		4-Bone™	X	IM/PA/SA/GA/DS/AT
	BCS		BONDBONE®	X	IM/PA/SA/GA/DS/AT
	BCP	OT medical	OToss Synthetic Bone	X	IM/PA/SA/GA/DS/AT
	BCP		OToss Synthetic Bone Inject	X	IM/PA/SA/GA/DS/AT
	BCS	REGEDENT	3D Bond	X	IM/PA/GA/DS/AT
	HA/BCS		Bond Apatite	X	IM/PA/GA/DS/AT
	BCP		OSOPIA	X	IM/PA/SA/GA/DS
	Collagen		OSSIX® Bone	X	IM/PA/SA/GA/DS/AT
	BCP	Shared Implantology	SinossGraft	X	IM/PA/SA/GA/DS
	BCP	(Novadento)	SinossGraft Resorb	X	IM/PA/SA/GA/DS
	BCP		SinossGraft Inject	X	IM/PA/SA/GA/DS
	β-TCP	Septodont	R.T.R. Granulat	X	IM/PA/SA/GA/DS/AT
	β-TCP		R.T.R. Spritze	X	IM/PA/SA/GA/DS/AT
	BCP	Straumann	Straumann® BoneCeramic	X	IM/PA/SA/GA/DS/AT

Continuation Table 2 Overview of the marketed augmentation materials in dentistry and oral and maxillofacial surgery. Status: April 2019. From: Yearbook of Implantology 2019, OEMUS MEDIA AG, Leipzig. Area of application: implantology (IM), periodontology (PA), sinus floor augmentation (SA), general augmentation (GA), defect surgery (DS), alveolar treatment (AT).

Type of material	Origin	Company	Product	Resorbable	Area of application
	BCP	Straumann (botiss)	maxresorb®	X	IM/PA/SA/GA/DS/AT
	BCP		maxresorb® inject	X	IM/PA/SA/GA/DS/AT
	BCP/ Collagen		collacone® max	X	IM/AT
	β-TCP	Sunstar Deutschland	calc-i-oss™CLASSIC	X	IM/PA/SA/GA/DS/AT
	β-TCP		easy-graft® CLASSIC	X	IM/PA/SA/GA/DS/AT
	BCP		easy-graft® CRYSTAL	X	IM/PA/SA/GA/DS/AT
	β-TCP	TAG Dental Systems	Sybone	X	IM/PA/SA/GA/DS/AT
	β-TCP	Thommen Medical	Ceros® TCP Granulat	X	IM/PA/SA/GA/DS/AT
	β-TCP		Ceros® TCP Putty	X	IM/PA/SA/GA/DS/AT
	BCS		3D Bond	X	IM/PA/GA/DS/AT
	HA/BCS		Bond Apatite	X	IM/PA/GA/DS/AT
	PLA/PGA	Zantomed	FISIOGRAFT Granulat	X	IM/PA/SA/GA/DS/AT
	PLA/PGA		FISIOGRAFT Gel	X	IM/PA/SA/GA/DS/AT
	PLA/PGA		FISIOGRAFT Schwamm	X	IM/PA/SA/GA/DS/AT
	HA		FISIOGRAFT BONE Granular	X	IM/PA/SA/GA/DS/AT
	HA	Zimmer Biomet	IngeniOs HA		IM/PA/SA/GA/DS/AT
	β-TCP/ Silicon		IngeniOs β-TCP bioaktiv	X	IM/PA/SA/GA/DS/AT
	Calciumphosphosilicate		Nova Bone	X	IM/PA/SA/GA/DS/AT
Autogen	Autologous vital	BTI	PRGF® Endoret®	X	IM/PA/SA/GA/DS/AT
	osteogenic cells	Champions-Implants	Smart Grinder	X	IM/SA/GA/DS/AT
		Schlumbohm	Autologer Knochen (KF T3)	X	IM/PA/SA/GA/DS

Continuation Table 2 Overview of the marketed augmentation materials in dentistry and oral and maxillofacial surgery. Status: April 2019. From: Yearbook of Implantology 2019, OEMUS MEDIA AG, Leipzig. Area of application: implantology (IM), periodontology (PA), sinus floor

rate of new bone formation in smokers, anamnestic periodontitis and poorly controlled diabetes [4–6]. Low vitamin D levels [7] and the use of PDE-5 inhibitors [8] might also play a negative role.

More consistent data exists on factors influencing implant success. Clinically, this data can be generalized to augmentations under certain circumstances. Studies associating osteoporosis, antiresorptive therapy, head and neck irradiation, selective serotonin reuptake inhibitors (SSRIs) and proton pump inhibitors (PPIs) with higher implant failure and complication rates exist [9–16].

Quintessence from the guideline

Strong contraindications against the use of bone substitute materials cannot be found in the literature. Patients with general diseases might be at a higher risk for complications or failures. In particular, the following factors should be determined in the medical history:

- smoking, periodontal disease, diabetes, bisphosphonates, osteoporosis, radiation, vitamin D levels as well as the intake of PDE-5 inhibitors (sildenafil), selective serotonin reuptake inhibitors (SSRI) and proton pump inhibitors (PPI).

1.3 The different biomaterials

In general, implants placed in the augmented area – regardless of the augmentation material – do not have a poorer long-term prognosis than implants placed in local pristine bone [17–25] (Table 2).

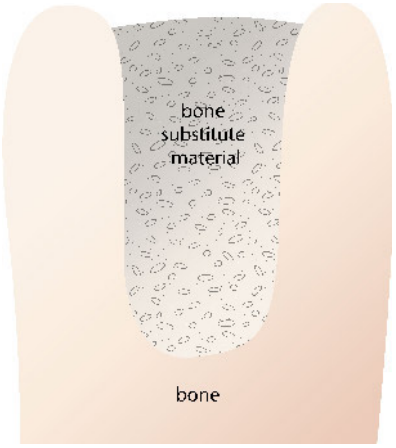
The status of autologous bone grafts as the "biological gold standard" can be found in some sources in the literature [26–28]. However, harvesting morbidity, resorption phenomena and the required volume also play a role when selecting the material [29–31]. Consequently, bone substitute materials that are artificial in nature (alloplastic/synthetic), from a foreign species (xenogeneic) or from human sources (allogeneic) come into focus; they present the main advantages of reduced perioperative morbidity and higher quantitative availability.

1.3.1 Allografts

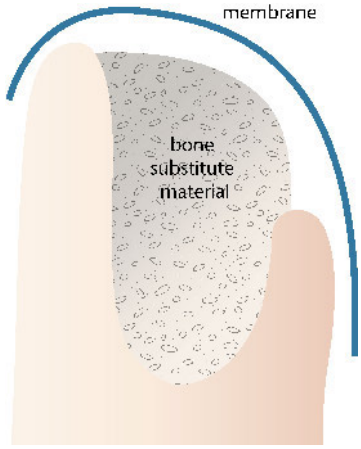
These bone substitute materials are obtained from human donors. As a result of the multitude of existing preparation processes, consistent scientific statements, for example, regarding the success and complication rates, are difficult to make, and the availability of data for certain materials in clinical situations is limited [32]. Fragments of cells and DNA could be detected in various allografts [33–37], although their clinical significance is controversial [38–40].

1.3.2 Xenografts

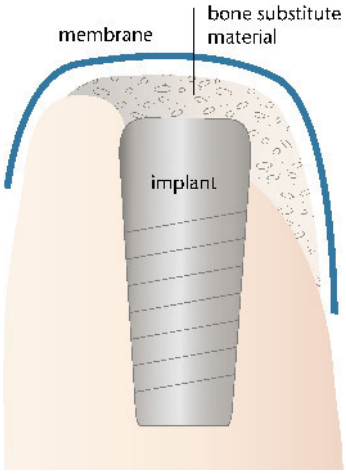
Bone substitute materials in this group can be obtained, for example, from cattle (bovine), pigs (porcine), horses (equine), but also from corals. Also, in this group, not every preparation has an equally good collection of data. Especially for some bovine products, there is a good collection of data with long observation periods [41–44]. These materials can be used to protect against resorption due to their very low resorption [41, 45, 46].



Drawing 1 Ridge preservation with preserved alveolar walls, use of particulate bone substitute material without a membrane.



Drawing 2 Ridge preservation in partially missing alveolar walls, use of particulate bone substitute with a resorbable collagen membrane.



Drawing 3 Dehiscence defect at the implant, regeneration with particulate bone substitute material using a resorbable collagen membrane.

1.3.3 Synthetic/alloplastic bone substitute materials

Since these materials are produced using purely artificial methods, they do not pose any problems in terms of immunological or infectious responses. Examples include hydroxyapatites, silicon-containing bioglasses, calcium phosphates and microporous composites. In direct comparison with xenografts, synthetic bone substitute materials appear to be equivalent at best for some indications, but otherwise inferior [47–50]. However, these materials can be used successfully for selected clinical indications [22].

Quintessence from the guideline

The available biomaterials have different properties, advantages and disadvantages. As a result, there is no one "gold standard". Moreover, it is advisable to check whether sufficient data is available for the material in question.

2. Regeneration of defects with high biological capacity

This group covers the treatment of defects whose regenerative capacity is classified as high according to 1.1. Characteristic to these clinical situations is that good osseous delimitations exist and that the soft tissue coat has not yet entered into the defect area.

2.1 Ridge preservation

The goal of ridge preservation procedures is to attenuate post-extraction resorption and preserve as much alveolar ridge and soft tissue volume as possible. The literature shows good prospects of success for a wide variety of protocols [51–55] (Drawing 1).

In a direct comparison, bovine xenogeneic material was superior [56] or equivalent [57] to allografts for this indication, although within the allograft material group, the demineralized freeze dried bone allograft (DFDBA) preparations appeared to be superior to other allogeneic preparations [32, 58]. There is also data describing the successful use of synthetic material [59] and platelet rich fibrin (A-PRF) [60] for alveolar ridge preservation.

2.2 The use of membranes/ guided bone regeneration (GBR) techniques for ridge preservation

Fundamental features of membranes used in GBR include the stabilization of a defect's shape, providing cell occlusivity and a barrier function [61]. When defects are present in the alveolar wall, the use of a membrane improves the result [53, 62–65] (Drawing 2). In comparing various types of membranes, resorbable collagen membranes show the most favorable ratio of success to complications [22].

2.3 Dehiscence defects at implants

Osseous deficits that occur when implants are placed are referred to as dehiscences and these are usually regenerated with a combination of biomaterials and membranes nowadays [22, 66–68], in which, autologous, allogeneic and xenogeneic materials, especially, demonstrate the best defect regeneration [22]. The best results for peri-implant augmentation performed simultaneously with implant placement can be achieved with the simultaneous use of a resorbable collagen membrane [22, 69] (Drawing 3).

Regeneration rates of up to 90 % are achievable, although it is clear that regenerated areas have a much better long-term prognosis than non-regenerated areas [22, 70].

2.4 Sinus lifting

Using a variety of techniques, sinus floor elevation aims to elevate Schneider's membrane in order to permit augmentation in the created space. There are many studies with a high level of evidence showing that it is irrelevant for the survival rate of the subsequently placed implants, whether they are placed in autologous bone, or in areas regenerated with bone substitute materials, and that their success rates are comparable. These results seem to be independent of the used bone substitute material or technique [71–77] (Drawing 4).

Quintessence from the guideline

Defects with intact bone walls can be regenerated with any biomaterial.

The largest amount of data is found for xenogeneic and allogeneic materials. In cases where a bone wall is lost, a membrane should be inserted to act as a barrier. Overall, clinical cases falling into this category have a relatively high success rate.

3. Regeneration of defects with low biological capacity

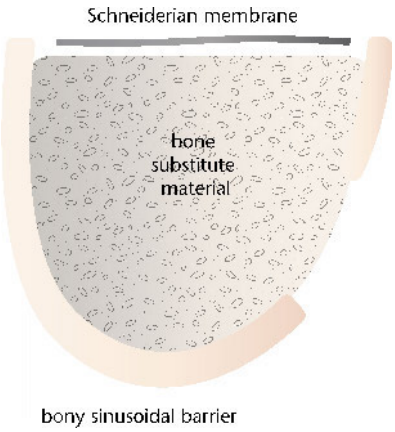
Defects whose regenerative capacity is classified as low according to 1.1 require significantly more technical and surgical effort than the situations analyzed so far. Lateral, vertical and, especially, combined lateral and vertical defects of the alveolar ridge fall into this group.

3.1 Regeneration with particulate bone substitute material (GBR techniques)

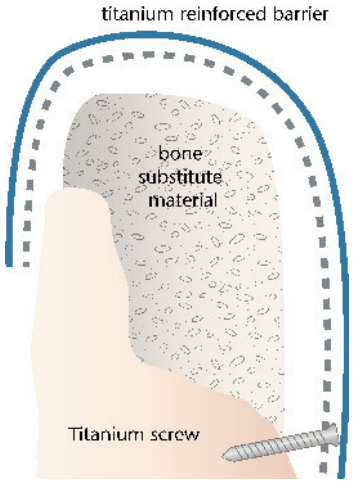
As long as the segment to be regenerated does not exceed 3 mm (laterally and/or vertically), particulate bone substitute material in combination with a barrier membrane can be used, analogous to the techniques presented in 2.2 and 2.3 [22] (Drawings 5 and 6).

If larger defects should be regenerated with the aid of particulate bone substitute materials, specific guided bone regeneration (GBR) techniques such as titanium-reinforced membranes, individualized titanium grids, or shell techniques are required; the bone substitute material appears to play a subordinate role compared to the barrier form [22, 78–81]. In particular, the use of the dimensionally stable barriers must be emphasized, as this is the only way to achieve similarly high levels of regeneration that would otherwise be possible solely with the aid of autologous bone blocks. In this context, CAD/CAM-produced titanium grids are of particular interest, as they reduce the intraoperative effort by virtue of their preoperative preparation, and they can be customized to accurately match the existing clinical situation [82–86].

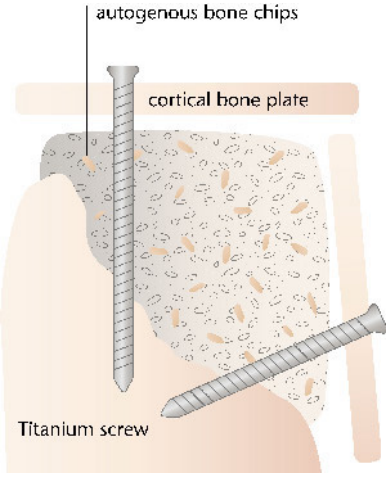
The risk of wound healing disturbances with consecutive dehiscence and the risk of implant/graft loss can only be reduced by customized soft tissue management [83, 86].



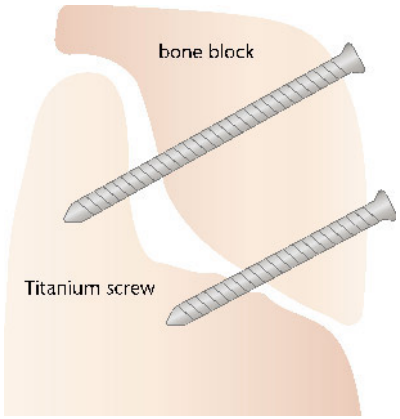
Drawing 4 Sinus lift with particulate bone substitute material.



Drawing 5 Lateral and vertical augmentation with a titanium mesh (then with additional resorbable collagen membrane "blue line") or as titanium-reinforced membrane. Fixation using screws or pins if necessary.



Drawing 6 Lateral and vertical augmentation using a cortical shell technique, filling with autologous bone chips or particulate bone substitute materials.



Drawing 7 Lateral and vertical augmentation with a bone block fixed using screws.

(Fig. 1, Drawings 1–7, Tab. 1 and 2: M. Tröltzsch)

Resorbable collagen membranes and PRF can improve dehiscence rates over titanium grids [85].

3.2 Regeneration with autologous blocks and blocks from bone substitute material

Numerous extraoral and intraoral donor sites are available for bone block harvesting to the experienced surgeon, though it is noteworthy to mention that evident differences with regard to the regenerative capacity from various harvesting sites exist. With intraoral blocks, defects up to 5 mm can be regenerated [22, 87, 88] (Drawing 7). For larger segments, bone from extraoral regions is recommended [22]; the iliac crest is frequently referred to as the "gold standard" based on the large amount of grafted osteoblasts [89, 90]. However, some limitations of autologous blocks need to be considered such as long-term resorption, as well as, the possible limited quantity of the volume that can be harvested and re-

moval morbidity of the graft [91–97]. As a result, the use of non-autologous blocks as an alternative is being investigated and the successful application of xenogeneic and allogeneic blocks have been described in the literature [31, 98–101]. However, direct comparisons between xenogeneic [22, 102] and allogeneic block grafts [22, 87, 103–106] have shown that autologous bone blocks are inferior in terms of regeneration outcomes and complication rates. Moreover, organic materials and DNA residues have also been detected in allogeneic and xenogeneic blocks [33–37, 89, 107, 108] and their effects are controversially discussed [34–36, 104, 105].

Overall, the available data for xenogeneic and allogeneic bone blocks is highly heterogeneous, partially controversial, and generally inadequate. The consistency of data for alloplastic blocks must be classified as even poorer.

Quintessence from the guideline

Defects up to 3 mm can be regenerated with particulate material in combination with a resorbable collagen membrane. Larger defects require either specialized GBR techniques or the preferable use of autologous blocks. Soft tissue management is of particular importance.

4. Conclusion

There is no "one" biomaterial that can be termed the gold standard. All available materials have advantages and disadvantages, which the practitioner must evaluate according to the indication. The treating physician and dental practitioner are responsible for selecting the appropriate material, which should be supported by sufficient data for the given case.

The preservation and regeneration of the alveolar ridge can be performed predictably using suitable materials. Ridge preservation is a well-documented standard technique which is suitable for reducing or even preventing subsequent major defects.

The regeneration of large defects with less surrounding bone is technically more demanding and difficult than the augmentation of small defects with more extensive surrounding bone. For defect segments of up to 3 mm (lateral and/or vertical), particulate bone substitute material in combination with resorbable membranes is sufficient for regeneration; on the other hand, for larger segments, specialized GBR techniques with stable barriers or preferably autologous bone blocks is required.

Conflicts of interest

The conflicts of interest can be found in the detailed version of the guideline "Implantological indications for the use of bone substitute materials" at www.online-dzz.de.

The full text of the guideline "Implantological indications for the use of bone substitute materials" can be freely downloaded from the DGZMK (www.dgzmk.de) and AWMF (www.awmf.org) websites.

References

1. Nahles S et al.: Bone physiology in human grafted and non-grafted extraction sockets – an immunohistochemical study. Clin Oral Implants Res 2013; 24: 812–819

2. Terheyden H: Knochenaugmentationen in der Implantologie. Dtsch Zahnärztl Z 2010; 65: 320–330

3. Cordaro L Terheyden H: ITI Treatment Guide. Alveolarkammaugmentationen bei Implantatpatienten: Ein zweizeitiges Konzept, ed. Terheyden H, Cordaro L: Vol. 7. Quintessenz, Berlin 2014

4. Sakkas A et al.: Risk factors for postoperative complications after procedures for autologous bone augmentation from different donor sites. J Craniomaxillofac Surg 2018; 46: 312–322

5. Zhang S et al.: Type 2 diabetes affects postextraction socket healing and influences first-stage implant surgery: a study based on clinical and animal evidence. Clin Implant Dent Relat Res 2019

6. Knabe C et al.: Effect of beta-tricalcium phosphate particles with varying porosity on osteogenesis after sinus floor augmentation in humans. Biomaterials 2008; 29: 2249–2258

7. Fretwurst T et al.: Vitamin D deficiency in early implant failure: two case reports. Int J Implant Dent 2016; 2: 24

8. Orchard E et al.: Sildenafil transiently delays early alveolar healing of tooth extraction sockets. Clin Surg 2017; 2: 1458

9. Farzad P, Andersson L, Nyberg J: Dental implant treatment in diabetic patients. Implant Dent 2002; 11: 262–267

10. Heitz-Mayfield LJ: Peri-implant diseases: diagnosis and risk indicators. J Clin Periodontol 2008; 35 (8 Suppl): 292–304

11. Gomez-de Diego R et al.: Indications and contraindications of dental implants in medically compromised patients: update. Med Oral Patol Oral Cir Bucal 2014; 19: e483–9

12. Grötz CWBA-N.S.H.R. M.U.K.A.: Zahnimplantate bei medikamentöser Behandlung mit Knochen Antiresorptiva (inkl. Bisphosphonate) Langversion 1.0, 2016. AWMF Registernummer: 083–026, 2016

13. Kandasamy B et al.: Long-term retrospective study based on implant success rate in patients with risk factor: 15-year follow-up. J Contemp Dent Pract 2018; 19: 90–93

14. Schimmel M et al.: Effect of advanced age and/or systemic medical conditions on dental implant survival: a systematic review and meta-analysis. Clin Oral Implants Res 2018; 29 (Suppl 16): 311–330

15. Carr AB et al.: Relationship between Selective Serotonin Reuptake Inhibitors and Risk of Dental Implant Failure. J Prosthodont 2019; 28: 252–257

16. Wu X et al.: Proton pump inhibitors and the risk of osseointegrated dental implant failure: a cohort study. Clin Implant Dent Relat Res 2017; 19: 222–232

17. Jensen SS, Terheyden H: Bone augmentation procedures in localized defects in the alveolar ridge: clinical results with different bone grafts and bone-substitute materials. Int J Oral Maxillofac Implants 2009; 24 (Suppl): 218–236

18. Barone A et al.: A randomized clinical trial to evaluate and compare implants placed in augmented versus non-augmented extraction sockets: 3-year results. J Periodontol 2012; 83: 836–846

19. Aloy-Prosper A et al.: The outcome of intraoral onlay block bone grafts on alveolar ridge augmentations: a systematic review. Med Oral Patol Oral Cir Bucal 2015; 20: e251–8

20. Motamedian SR, Khojaste M, Khojasteh A: Success rate of implants placed in autogenous bone blocks versus allogenic bone blocks: a systematic literature review. Ann Maxillofac Surg 2016; 6: 78–90

21. Tran DT et al.: Survival of dental implants placed in grafted and nongrafted bone: a retrospective study in a university setting. Int J Oral Maxillofac Implants 2016; 31: 310–317

22. Troeltzsch M et al.: Clinical efficacy of grafting materials in alveolar ridge augmentation: a systematic review. J Craniomaxillofac Surg 2016; 44: 1618–1629

23. Urban IA et al.: Long-term evaluation of peri-implant bone level after reconstruction of severely atrophic edentulous maxilla via vertical and horizontal guided bone regeneration in combination with sinus augmentation: a case series with 1 to 15 years of loading. Clin Implant Dent Relat Res 2017; 19: 46–55

24. Marconcini S et al.: Clinical outcomes of implants placed in ridge-preserved versus nonpreserved sites: a 4-year randomized clinical trial. Clin Implant Dent Relat Res 2018; 20: 906–914

25. Salvi GE, Monje A, Tomasi C: Long-term biological complications of dental implants placed either in pristine or in augmented sites: a systematic review and meta-analysis. Clin Oral Implants Res 2018; 29 (Suppl 16): 294–310

26. Bauer TW, Muschler GF: Bone graft materials. An overview of the basic science. Clin Orthop Relat Res 2000; 371: 10–27

27. Fretwurst T et al.: Long-term retrospective evaluation of the peri-implant bone level in onlay grafted patients with iliac bone from the anterior superior iliac crest. J Craniomaxillofac Surg 2015; 43(6): 956–960

28. Sakkas A et al.: Autogenous bone grafts in oral implantology – is it still a "gold standard"? A consecutive review of 279 patients with 456 clinical procedures. Int J Implant Dent 2017; 3(1): 23

29. Chiapasco M, Zaniboni M, Rimondini L: Autogenous onlay bone grafts vs. alveolar distraction osteogenesis for the correction of vertically deficient edentulous ridges: a 2–4-year prospective study on humans. Clin Oral Implants Res 2007; 18(4): 432–440

30. Felice P et al.: Vertical ridge augmentation of the atrophic posterior mandible with interpositional block grafts: bone from the iliac crest versus bovine anorganic bone. Eur J Oral Implantol 2008; 1: 183–198

31. Dahlin C, Johansson A: Iliac crest autogenous bone graft versus alloplastic graft and guided bone regeneration in the reconstruction of atrophic maxillae: a 5-year retrospective study on cost-effectiveness and clinical outcome. Clin Implant Dent Relat Res 2011; 13: 305–310

32. Wood RA, Mealey BL: Histologic comparison of healing after tooth extraction with ridge preservation using mineralized versus demineralized freeze-dried bone allograft. J Periodontol 2012; 83: 329–336

33. Fretwurst T et al.: Comparison of four different allogeneic bone grafts for alveolar ridge reconstruction: a preliminary histologic and biochemical analysis. Oral Surg Oral Med Oral Pathol Oral Radiol 2014; 118: 424–431

34. Ghanaati S et al.: Potential lack of "standardized" processing techniques for production of allogeneic and xenogeneic bone blocks for application in humans. Acta Biomater 2014; 10: 3557–3562

35. Fretwurst T et al.: Detection of major histocompatibility complex molecules in processed allogeneic bone blocks for use in alveolar ridge reconstruction. Oral Surg Oral Med Oral Pathol Oral Radiol 2018

36. Lorenz J et al.: Allogeneic bone block for challenging augmentation – a clinical, histological, and histomorphometrical investigation of tissue reaction and new bone formation. Clin Oral Investig 2018; 22: 3159–3169

37. Li G et al.: Current updates on bone grafting biomaterials and recombinant human growth factors implanted biotherapy for spinal fusion: a review of human clinical studies. Curr Drug Deliv 2019; 16: 94–110

38. Solakoglu O et al.: Characterization of circulating DNA in plasma of patients after allogeneic bone grafting. Clin Oral Investig 2019; 23: 4243–4253

39. Solakoglu O et al.: Histological and immunohistochemical comparison of two different allogeneic bone grafting materials for alveolar ridge reconstruction: a prospective randomized trial in humans. Clin Implant Dent Relat Res 2019; 21: 1002–1016

40. Stopa Z et al.: Evaluation of the safety and clinical efficacy of allogeneic bone grafts in the reconstruction of the maxilla and mandible. Transplant Proc 2018; 50: 2199–2201

41. Klein MO et al.: Long-term bony integration and resorption kinetics of a xenogeneic bone substitute after sinus floor augmentation: histomorphometric analyses of human biopsy specimens. Int J Periodontics Restorative Dent 2013; 33: e101–10

42. Majzoub J et al.: The influence of different grafting materials on alveolar ridge preservation: a systematic review. J Oral Maxillofac Res 2019; 10: e6

43. Mendoza-Azpur G et al.: Horizontal ridge augmentation with guided bone regeneration using particulate xenogenic bone substitutes with or without autogenous block grafts: a randomized controlled trial. Clin Implant Dent Relat Res 2019; 21: 521–530

44. Thoma DS et al.: Efficacy of lateral bone augmentation performed simultaneously with dental implant placement: a systematic review and meta-analysis. J Clin Periodontol 2019; 46 (Suppl 21): 257–276

45. Mordenfeld A et al.: Histological and histomorphometrical analyses of biopsies harvested 11 years after maxillary sinus floor augmentation with deproteinized bovine and autogenous bone. Clin Oral Implants Res 2010; 21: 961–970

46. Naenni N et al.: Efficacy of lateral bone augmentation prior to implant placement: a systematic review and meta-analysis. J Clin Periodontol 2019; 46 (Suppl 21): 287–306

47. Dau M et al.: Bone formation in mono cortical mandibular critical size defects after augmentation with two synthetic nanostructured and one xenogenous hydroxyapatite bone substitute – in vivo animal study. Clin Oral Implants Res 2016; 27: 597–603

48. Hung CC et al.: Bone formation following sinus grafting with an alloplastic biphasic calcium phosphate in Lanyu Taiwanese mini-pigs. J Periodontol 2019

49. Lorenz J et al.: Volumetric analysis of bone substitute material performance within the human sinus cavity of former head and neck cancer patients: a prospective, randomized clinical trial. Ann Maxillofac Surg 2016; 6: 175–181

50. Sanz M, Vignoletti F: Key aspects on the use of bone substitutes for bone regeneration of edentulous ridges. Dent Mater 2015; 31: 640–647

51. Barone A et al.: A prospective, randomized, controlled, multicenter evaluation of extraction socket preservation comparing two bovine xenografts: clinical and histologic outcomes. Int J Periodontics Restorative Dent 2013; 33: 795–802

52. Avila-Ortiz G et al.: Effect of alveolar ridge preservation after tooth extraction: a systematic review and meta-analysis. J Dent Res 2014; 93: 950–958

53. Avila-Ortiz G et al.: Effectiveness of three different alveolar ridge preservation techniques: a pilot randomized controlled trial. Int J Periodontics Restorative Dent 2014; 34: 509–521

54. Bonanini M et al.: Effect of alveolar ridge preservation after tooth extraction: a systematic review and meta-analysis. Biomed Res Int 2014; 93: 950–958

55. Willenbacher M et al.: The effects of alveolar ridge preservation: a meta-analysis. Clin Implant Dent Relat Res 2016; 18: 1248–1268

56. Scheyer ET et al.: A randomized, controlled, multicentre clinical trial of post-extraction alveolar ridge preservation. J Clin Periodontol 2016; 43: 1188–1199

57. Sadeghi R et al.: A randomized controlled evaluation of alveolar ridge preservation following tooth extraction using

deproteinized bovine bone mineral and demineralized freeze-dried bone allograft. Dent Res J (Isfahan) 2016; 13: 151–159

58. Whetman J, Mealey BL: Effect of healing time on new bone formation after tooth extraction and ridge preservation with demineralized freeze-dried bone allograft: a randomized controlled clinical trial. J Periodontol 2016; 87: 1022–1029

59. Ioannou AL et al.: Evaluation of the bone regeneration potential of bioactive glass in implant site development surgeries: a systematic review of the literature. Clin Oral Investig 2015; 19: 181–191

60. Schliephake H et al.: Drugs and diseases: summary and consensus statements of group 1. The 5(th) EAO Consensus Conference 2018. Clin Oral Implants Res 2018; 29 (Suppl 18): 93–99

61. Elgali I et al.: Guided bone regeneration: materials and biological mechanisms revisited. Eur J Oral Sci 2017; 125: 315–337

62. Barone A et al.: Xenograft versus extraction alone for ridge preservation after tooth removal: a clinical and histomorphometric study. J Periodontol 2008; 79: 1370–1377

63. Brkovic BM et al.: Beta-tricalcium phosphate/type I collagen cones with or without a barrier membrane in human extraction socket healing: clinical, histologic, histomorphometric, and immunohistochemical evaluation. Clin Oral Investig 2012; 16: 581–590

64. Fischer KR et al.: Dimensional evaluation of different ridge preservation techniques with a bovine xenograft: a randomized controlled clinical trial. Int J Periodontics Restorative Dent 2018; 38: 549–556

65. Jung RE et al.: Combined use of xenogeneic bone substitute material covered with a native bilayer collagen membrane for alveolar ridge preservation: a randomized controlled clinical trial. Clin Oral Implants Res 2018; 29: 522–529

66. Hassan KS: Autogenous bone graft combined with polylactic polyglycolic acid polymer for treatment of dehiscence around immediate dental implants. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009; 108: e19–25

67. Jung RE et al.: Cone beam computed tomography evaluation of regenerated buccal bone 5 years after simultaneous implant placement and guided bone regeneration procedures – a randomized, controlled clinical trial. Clin Oral Implants Res 2015; 26: 28–34

68. Llambes F, Silvestre FJ, Caffesse R: Vertical guided bone regeneration with bioabsorbable barriers. J Periodontol 2007; 78: 2036–2042

69. Le BT, Borzabadi-Farahani A: Simultaneous implant placement and bone grafting with particulate mineralized allograft in sites with buccal wall defects, a three-year follow-up and review of literature. J Craniomaxillofac Surg 2014; 42: 552–559

70. Jung RE et al.: A randomized controlled clinical trial comparing small buccal dehiscence defects around dental implants treated with guided bone regeneration or left for spontaneous healing. Clin Oral Implants Res 2017; 28: 348–354

71. Al-Nawas B, Schiegnitz E: Augmentation procedures using bone substitute materials or autogenous bone – a systematic review and meta-analysis. Eur J Oral Implantol 2014; 7 (Suppl 2): S219–34

72. Danesh-Sani SA, Engebretson SP, Janal MN: Histomorphometric results of different grafting materials and effect of healing time on bone maturation after sinus floor augmentation: a systematic review and meta-analysis. J Periodontal Res 2017; 52: 301–312

73. Starch-Jensen T et al.: A systematic review and meta-analysis of long-term studies (five or more years) assessing maxillary sinus floor augmentation. Int J Oral Maxillofac Surg 2018; 47: 103–116

74. Starch-Jensen T et al.: Maxillary sinus floor augmentation with synthetic bone substitutes compared with other grafting materials: a systematic review and meta-analysis. Implant Dent 2018; 27: 363–374

75. Jensen T et al.: Maxillary sinus floor augmentation with Bio-Oss or Bio-Oss mixed with autogenous bone as graft: a systematic review. Clin Oral Implants Res 2012; 23: 263–273

76. Jensen T et al.: Bone-to-implant contact after maxillary sinus floor augmentation with Bio-Oss and autogenous bone in different ratios in mini pigs. Clin Oral Implants Res 2013; 24: 635–644

77. Esposito M, Felice P, Worthington HV: Interventions for replacing missing teeth: augmentation procedures of the maxillary sinus. Cochrane Database Syst Rev 2014: Cd008397

78. Rocchietta I et al.: Vertical bone augmentation with an autogenous block or particles in combination with guided bone regeneration: a clinical and histological preliminary study in humans. Clin Implant Dent Relat Res 2016; 18: 19–29

79. Seiler M et al.: Customized lattice structure in reconstruction of three-dimensional alveolar defects. Int J Comput Dent 2018; 21: 261–267

80. Seiler M et al.: Customized titanium lattice structure in three-dimensional alveolar defect: an initial case letter. J Oral Implantol 2018; 44: 219–224

81. Urban IA et al.: Effectiveness of vertical ridge augmentation interventions. A systematic review and meta-analysis. J Clin Periodontol, 2019; 46 (Suppl 21): 319–339

82. Ciocca L et al.: Direct metal laser sintering (DMLS) of a customized titanium mesh for prosthetically guided bone regeneration of atrophic maxillary arches. Med Biol Eng Comput 2011; 49: 1347–1352

83. Ciocca L et al.: Prosthetically CAD-CAM-guided bone augmentation of atrophic jaws using customized titanium mesh: preliminary results of an open prospective study. J Oral Implantol 2018; 44: 131–137

84. Hartmann A et al.: Evaluation of risk parameters in bone regeneration using a customized titanium mesh: results of a clinical study. Implant Dent 2019; 28: 543–550

85. Lorenz J et al.: Individualized titanium mesh combined with platelet-rich fibrin and deproteinized bovine bone: a new approach for challenging augmentation. J Oral Implantol 2018; 44: 345–351

86. Sagheb K et al.: Clinical outcome of alveolar ridge augmentation with individualized CAD-CAM-produced titanium mesh. Int J Implant Dent 2017; 3: 36

87. Khojasteh A et al.: Localized bone augmentation with cortical bone blocks tented over different particulate bone substitutes: a retrospective study. Int J Oral Maxillofac Implants 2012; 27: 1481–1493

88. Khojasteh A, Morad G, Behnia H: Clinical importance of recipient site characteristics for vertical ridge augmentation: a systematic review of literature and proposal of a classification. J Oral Implantol 2012

89. Wein M et al.: Pilot investigation of the molecular discrimination of human osteoblasts from different bone entities. J Craniomaxillofac Surg 2015; 43: 1487–1493

90. Wein M et al.: Differential osteopontin expression in human osteoblasts derived from iliac crest and alveolar bone and its role in early stages of angiogenesis. J Bone Miner Metab 2019; 37: 105–117

91. Maestre-Ferrin L, Boronat-Lopez A, Penarrocha-Diago M: Augmentation procedures for deficient edentulous ridges, using onlay autologous grafts: an update. Med Oral Patol Oral Cir Bucal 2009; 14: e402–7

92. Mertens C et al.: Early bone resorption after vertical bone augmentation – a comparison of calvarial and iliac grafts. Clin Oral Implants Res 2013; 24: 820–825

93. Smolka W: Calvarial grafts for alveolar ridge reconstruction prior to dental implant placement: an update. Oral Maxillofac Surg 2014; 18: 381–385

94. Nkenke E, Neukam FW: Autogenous bone harvesting and grafting in advanced jaw resorption: morbidity, resorption and implant survival. Eur J Oral Implantol 2014; 7 (Suppl 2): S203–17

95. Barone A et al.: Morbidity associated with iliac crest harvesting in the treatment of maxillary and mandibular atrophies: a 10-year analysis. J Oral Maxillofac Surg 2011; 69: 2298–2304

96. Kuik K et al.: Donor site morbidity of anterior iliac crest and calvarium bone grafts: a comparative case-control study. J Craniomaxillofac Surg 2016; 44: 364–368

97. Putters TF et al.: Morbidity of anterior iliac crest and calvarial bone donor graft sites: a 1-year randomized controlled trial. Int J Oral Maxillofac Surg 2018; 47: 1474–1480

98. Bonanini M et al.: Vertical ridge augmentation using xenogenous bone blocks: a comparison between the flap and tunneling procedures. Biomed Res Int 2014; 72: 1660–1670

99. Pereira E et al.: Horizontal resorption of fresh-frozen corticocancellous bone blocks in the reconstruction of the atrophic maxilla at 5 months. Clin Implant Dent Relat Res 2014

100. Blume O et al.: Treatment of severely resorbed maxilla due to peri-implantitis by guided bone regeneration using a customized allogenic bone block: a case report. Materials (Basel) 2017; 10: 1213

101. Kloss FR, Offermanns V, Kloss-Brandstatter A: CEComparison of allogeneic and autogenous bone grafts for augmentation of alveolar ridge defects – a 12-month retrospective radiographic evaluation. Clin Oral Implants Res 2018

102. Pistilli R et al.: Blocks of autogenous bone versus xenografts for the rehabilitation of atrophic jaws with dental implants: preliminary data from a pilot randomised controlled trial. Eur J Oral Implantol 2014; 7: 153–171

103. Chiapasco M et al.: Fresh frozen versus autogenous iliac bone for the rehabilitation of the extremely atrophic maxilla with onlay grafts and endosseous implants: preliminary results of a prospective comparative study. Clin Implant Dent Relat Res 2013

104. Lumetti S et al.: Fresh-frozen bone blocks for horizontal ridge augmentation in the upper maxilla: 6-month outcomes of a randomized controlled trial. Clin Implant Dent Relat Res 2014; 16(1): 116–123

105. Lumetti S, Galli C: Correlation between density and resorption of fresh-frozen and autogenous bone grafts 2014; 2014: 508328

106. Leong DJ et al.: Comparison between sandwich bone augmentation and allogenic block graft for vertical ridge augmentation in the posterior mandible. J Periodontal Implant Sci 2015; 24: 4–12

107. Kubosch EJ et al.: Clinical trial and in-vitro study comparing the efficacy of treating bony lesions with allografts versus synthetic or highly-processed xenogeneic bone grafts. BMC Musculoskelet Disord 2016; 17: 77

108. Coutinho LF et al.: Presence of cells in fresh-frozen allogeneic bone grafts from different tissue banks. Braz Dent J 2017; 28: 152–157

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