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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).

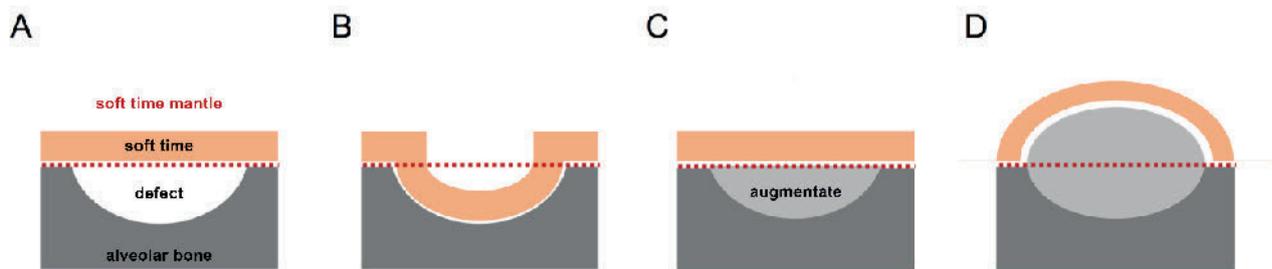


Figure 1 Schematic representation of the bone shape, the soft tissue coat and an augmentation inside and outside of the soft tissue coat. The representation applies to horizontal, vertical and combined alveolar ridge defects. The soft tissue coat (red line) describes the natural dimension of the alveolar 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	Resorb-able	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	
		Zimmer Biomet	maxgraft® Granulat cortico-spongiös	X	IM/PA/SA/GA/DS/AT	
			maxgraft® Block	X	IM/GA/DS	
			maxgraft® bonebuilder	X	IM/GA/DS	
			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	
		Xenoge-neic	Equine	American Dental Systems Mectron	OsteoBio® SP-Block (Bone Splitting/Spread.)	X
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			OsteoBio® Gen-Os	X	IM/PA/SA/GA/DS
				OsteoBio® Apatos (Mix)		IM/PA/SA/GA/DS/AT
				OsteoBio® mp3	X	IM/PA/SA/GA/DS/AT
				OsteoBio® GTO®	X	IM/PA/SA/GA/DS/AT
				OsteoBio® Putty	X	IM/PA/GA
			OsteoBio® SP-Block (Bone Splitting/Spread.)	X	GA	
			OsteoBio® Bone Lamina Soft (Barrier)	X	IM/GA/DS	
			CAMLOG Champions-Implants	MinerOss® XP	X	IM/PA/SA/GA/DS/AT
				Matri™ Bone	X	IM/PA/SA/GA/DS/AT
				CollaWin!	X	IM/PA/SA/GA/DS/AT
CERASORB® Foam	X			IM/SA/GA/DS/AT		
Bovine	Curasan (Vertrieb: mds)			Symbios® Xenograft-Granulat	X	IM/PA/SA/GA/DS/AT
			Geistlich Bio-Oss® COLLAGEN	X	IM/PA/SA/GA/DS/AT	
			Geistlich Bio-Oss® COLLAGEN	X	IM/PA/SA/GA/DS/AT	
			The Graft		IM/PA/SA/GA/DS/AT	
			OSSIX® VOLUMAX	X	IM/GA/DS	
	Straumann (botiss) Thommen Medical		OSSIX® Bone	X	IM/PA/SA/GA/DS/AT	
			collacone® max	X	IM/AT	
			The Graft		IM/PA/SA/GA/DS/AT	
			OSSIX® Bone		IM/PA/SA/GA/DS/AT	
			BEGO Implant Systems	BEGO OSS		IM/PA/SA/GA/DS/AT
Bovine	BioHorizons (CAMLOG Dtl.)		MinerOss®-X	X	IM/PA/SA/GA/DS/AT	
			Bioimplon CAMLOG	Hypro-Oss®	X	IM/PA/SA/GA/DS/AT
				MinerOss® X	X	IM/PA/SA/GA/DS/AT
				MinerOss® X Collagen	X	IM/PA/SA/GA/DS/AT
				CompactBone B	X	IM/PA/SA/GA/DS/AT
	Dentegris Deutschland 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	
			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	Resorb-able	Area of application
plant-based		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	
		Dentsply Sirona	Frios® Algapore®	X	IM/PA/SA/GA/DS/AT
		Symbios® Biphasisches KAM	X	IM/PA/SA/GA/DS/AT	
		Gebr. Martin/KLS	Maratrix	X	IM/PA/SA/GA/DS/AT
Martin					
SIC invent	SIC nature graft	X	IM/PA/SA/GA/DS/AT		
Synthetic	HA/Collagen/ Glycosamino- glycans Sodium hyaluronate BCP β-TCP BCP Kollagen β-TCP β-TCP β-TCP β-TCP β-TCP β-TCP β-TCP HA Calcium sulfate/ β-TCP BCP Collagen Collagen Collagen Collagen BCP HA/SiO ₂ HA/SiO ₂ HA/SiO ₂ BCP β-TCP BCP β-TCP HA HA/BCS BCP BCS BCP BCP BCS HA/BCS BCP Collagen BCP BCP BCP β-TCP β-TCP BCP	ACTEON Germany	BIOSTITE	X	IM/PA/SA/GA/DS
		Argon Dental	OsteoGel® Hyaluron	X	IM/PA/SA/GA/DS/AT
		BEGO Implant Systems	BEGO OSS S	X	IM/PA/SA/GA/DS/AT
		Bicon	SynthoGraft™	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® Classic	X	IM/SA/GA/DS/AT
		CERASORB® M	X	IM/SA/GA/DS/AT	
		CERASORB® Perio	X	PA	
		CERASORB® Plus	X	IM/SA/GA/DS/AT	
		CERASORB® Paste	X	IM/PA/SA/GA/DS/AT	
		CERASORB® Foam	X	IM/SA/GA/DS/AT	
		CERASORB® Formteile	X	DC	
		Osbone®		IM/PA/SA/GA/DS/AT	
		ethOss	X	IM/PA/SA/GA/DS/AT	
		Demedi-Dent			
		CompactBone S	X	IM/PA/SA/GA/DS/AT	
		Dentegris Deutschland			
		Dentium/iCT Europe			
		OSTEON™		IM/PA/SA/GA/DS/AT	
		OSTEON™ Sinus & Lifting		IM/PA/SA/GA/DS/AT	
		OSTEON II™		IM/PA/SA/GA/DS/AT	
		OSTEON II™ Sinus & Lifting		IM/PA/SA/GA/DS/AT	
		Dr. Ihde Dental			
		Nanos®	X	IM/PA/SA/GA/DS/AT	
		Hager & Meisinger			
		NanoBone® granulate	X	IM/PA/SA/GA/DS/AT	
		NanoBone® block	X	IM/GA/DS	
		NanoBone® QD	X	IM/PA/SA/GA/DS/AT	
		Henry Schein			
		BONITmatrix®	X	IM/PA/SA/GA/DS/AT	
		K.S.I. Bauer-Schraube			
		calc-i-oss™	X	IM/PA/SA/GA/DS/AT	
		easy-graft®	X	IM/PA/SA/GA/DS/AT	
		LASAK			
		PORESORB-TCP	X	IM/PA/SA/GA/DS/AT	
		OssaBase® -HA	X	IM/PA/SA/GA/DS/AT	
		MIS Implants Technologies			
		4MATRIX	X	IM/PA/SA/GA/DS/AT	
		4-Bone™	X	IM/PA/SA/GA/DS/AT	
		BONDBONE®	X	IM/PA/SA/GA/DS/AT	
		OT medical			
OToss Synthetic Bone	X	IM/PA/SA/GA/DS/AT			
OToss Synthetic Bone Inject	X	IM/PA/SA/GA/DS/AT			
REGEDENT					
3D Bond	X	IM/PA/GA/DS/AT			
Bond Apatite	X	IM/PA/GA/DS/AT			
OSOPIA	X	IM/PA/SA/GA/DS			
OSSIX® Bone	X	IM/PA/SA/GA/DS/AT			
Shared Implantology					
SinossGraft	X	IM/PA/SA/GA/DS			
(Novadento)					
SinossGraft Resorb	X	IM/PA/SA/GA/DS			
SinossGraft Inject	X	IM/PA/SA/GA/DS			
Septodont					
R.T.R. Granulat	X	IM/PA/SA/GA/DS/AT			
R.T.R. Spritze	X	IM/PA/SA/GA/DS/AT			
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	Resorb-able	Area of application
BCP BCP/ Collagen β-TCP β-TCP BCP β-TCP β-TCP β-TCP BCS HA/BCS PLA/PGA PLA/PGA PLA/PGA HA HA β-TCP/ Silicon Calciumphos- phosilicate	Straumann (botiss)		maxresorb®	X	IM/PA/SA/GA/DS/AT
			maxresorb® inject	X	IM/PA/SA/GA/DS/AT
			collacone® max	X	IM/AT
	Sunstar Deutschland		calc-i-oss™CLASSIC	X	IM/PA/SA/GA/DS/AT
			easy-graft® CLASSIC	X	IM/PA/SA/GA/DS/AT
	TAG Dental Systems		easy-graft® CRYSTAL	X	IM/PA/SA/GA/DS/AT
			Sybone	X	IM/PA/SA/GA/DS/AT
	Thommen Medical		Ceros® TCP Granulat	X	IM/PA/SA/GA/DS/AT
			Ceros® TCP Putty	X	IM/PA/SA/GA/DS/AT
	Zantomed		3D Bond	X	IM/PA/GA/DS/AT
			Bond Apatite	X	IM/PA/GA/DS/AT
			FISIOGRAFT Granulat	X	IM/PA/SA/GA/DS/AT
			FISIOGRAFT Gel	X	IM/PA/SA/GA/DS/AT
			FISIOGRAFT Schwamm	X	IM/PA/SA/GA/DS/AT
			FISIOGRAFT BONE Granular	X	IM/PA/SA/GA/DS/AT
IngeniOs HA			X	IM/PA/SA/GA/DS/AT	
Zimmer Biomet		IngeniOs β-TCP bioaktiv	X	IM/PA/SA/GA/DS/AT	
		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 Schlumbohm	Smart Grinder Autologer Knochen (KF T3)	X X	IM/SA/GA/DS/AT 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).

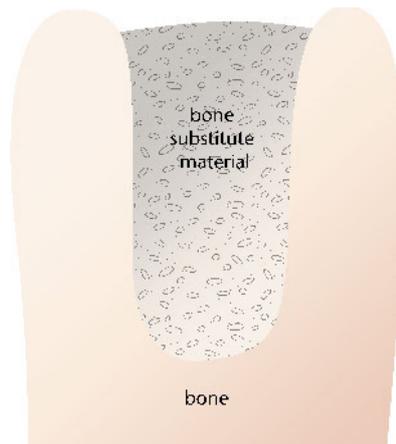
The status of autologous bone grafts as the “biological gold standard” can be found in some sources in the literature [26–28]. However, harvesting morbidity, resorption phenomena and the required volume also play a role when selecting the material [29–31]. Consequently, bone substitute materials that 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

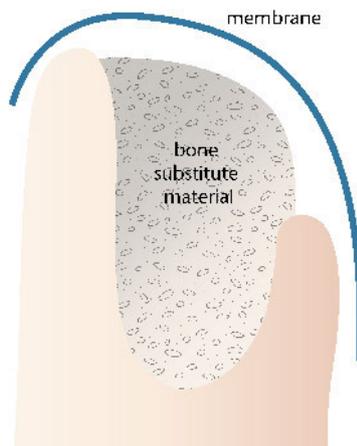
These bone substitute materials are obtained from human donors. As a result of the multitude of existing preparation processes, consistent scientific statements, for example, regarding the success and complication rates, are difficult to make, and the availability of data for certain materials in clinical 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

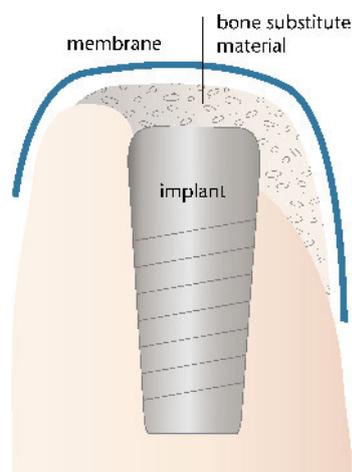
Bone substitute materials in this group can be obtained, for example, from cattle (bovine), pigs (porcine), horses (equine), but also from corals. Also, in this group, not every preparation has an equally good collection of data. Especially for some bovine products, there is a good collection of data 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

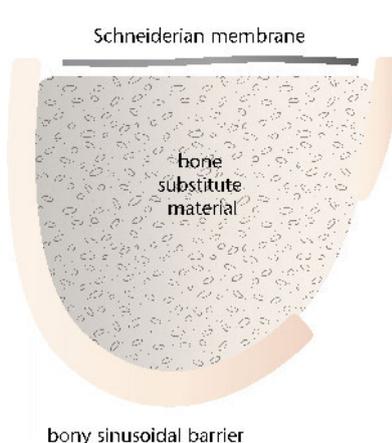
Defects whose regenerative capacity is classified as low according to 1.1 require significantly more technical and surgical effort than the situations analyzed so far. Lateral, vertical and, especially, combined lateral and vertical defects of the alveolar ridge fall into this group.

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].

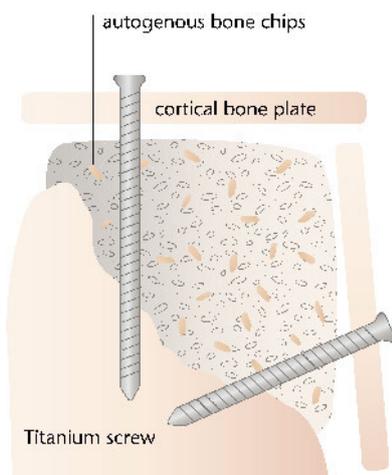
The risk of wound healing disturbances with consecutive dehiscence and the risk of implant/graft loss can only be reduced by customized soft tissue management [83, 86].



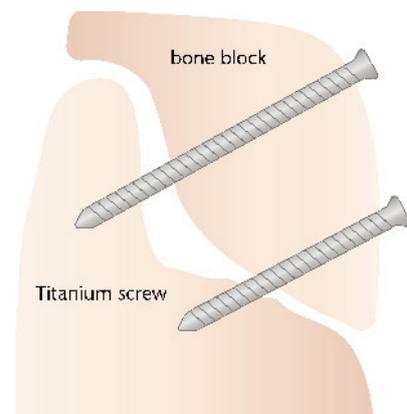
Drawing 4 Sinus lift with particulate bone substitute material.



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 capac-

ity 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.

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