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Clinical outcomes of GBR procedures to correct peri-implant dehiscences and fenestrations: a systematic review

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Abstract

Objective: To analyze the clinical outcomes of endosseous implants following guided bone regeneration (GBR) procedures to correct dehiscence/fenestration defects associated with implant placement.

Methods/Search strategy: A Medline search was performed for human studies published in English focusing on GBR procedures for the correction of dehiscence/fenestration defects associated with the placement of screw-shaped titanium implants. The selected studies had to include at least 10 consecutively treated patients with a minimum follow-up of 12 months after the start of prosthetic loading. The clinical outcomes in terms of the complication rate of the GBR procedure, implant survival, and stability of marginal soft tissues around implants were evaluated.

Results: Seven publications were included in this review. A total of 238 patients received 374 implants. Defects were treated with resorbable or non-resorbable membranes, in association with or without graft materials. Patients were followed for 1–10 years after the start of prosthetic loading. In the postoperative period, 20% of the non-resorbable membranes and 5% of the resorbable ones underwent exposure/infection. However, in the majority of cases, a complete or an almost complete coverage of the initial defect was obtained. The overall survival rate of implants, irrespective of the type of membrane and grafting materials, was 95.7% (range: 84.7–100%). No significant modifications of probing depth and/or variation of clinical attachment level around implants were observed during the follow-up period.

Conclusion: Despite the favorable results obtained, it was difficult to draw a significant conclusion as far as the more reliable grafting material and membrane barrier for the correction of dehiscence/fenestration defects are concerned, due to the limited sample of patients and the wide variety of grafting materials and membranes, used alone or in combination. Moreover, due to the lack of randomized clinical trials, it was impossible to demonstrate that such augmentation procedures are actually needed to allow the long-term survival of implants.

Dental rehabilitation of partially or totally edentulous patients with oral implants has become a routine treatment modality in the last decades, with reliable long-term results (Albrektsson et al. 1986; van Steenberghe 1989; van Steenberghe et al. 1990; Lindquist et al. 1996; Buser et al. 1997; Arvidson et al. 1998; Lekholm et al. 1999; Brocard et al. 2000; Weber et al. 2000; Leonhardt et al. 2002; Becktor et al. 2004; Esposito et al. 2004). However, unfavorable local conditions of the alveolar ridge, due to atrophy, periodontal disease, and trauma sequelae, may provide insufficient bone volume, which may potentially compromise the long-term survival

of implants or render implant placement incorrect from a functional and esthetic viewpoint.

In particular, if a horizontal defect is present, implant placement may result in a dehiscence or a fenestration defect, exposing part of the implant body. As the dehiscence or fenestration may impair implant success or increase the risk of failure, GBR procedures that allow spaces maintained by barrier membranes to be filled with bone (Dahlin et al. 1989, 1991; Hämmerle et al. 1996, 2002) have been used to generate bone over the exposed implant surface at the time of implant placement.

GBR procedures in case of dehiscence/fenestration defects can be obtained with resorbable or non-resorbable membranes, in association with a variety of graft materials, such as autogenous bone (AB), allografts, xenografts, and alloplastic materials.

Yet, despite an increasing number of publications related to the correction of dehiscence/fenestration defects, considerable controversy still exists regarding the need for such augmentation procedures and the choice of the more suitable and reliable membrane and/or grafting material. This is frequently because the publications are of insufficient methodological quality (inadequate sample size, lack of well-defined exclusion and inclusion criteria, insufficient follow-up, lack of well-defined success criteria, etc.).

Objectives

The objective of this review was to analyze publications related to augmentation procedures used to correct dehiscence/fenestration defects associated with the placement of screw-shaped titanium implants. Augmentation was obtained either with membrane barriers alone or in association with AB or bone substitute materials. The clinical outcomes in terms of the complication rate of the GBR procedure, implant survival/success rates, and stability of marginal hard and soft tissues around implants were evaluated.

Material and methods

Search strategy

A Medline (PubMed) search was performed for human studies, including articles published in English from 1986 to December 2008. To expand this, a hand search of journal issues from 1986 through December 2008 was undertaken of the following journals: *Clinical Oral Implants Research*, *The International Journal of Oral & Maxillofacial Implants*, *Journal of Oral and Maxillofacial Surgery*, *International Journal of Oral and Maxillofacial Surgery*, *Journal of Cranio-Maxillo-Facial Surgery*, *Journal of Prosthetic Dentistry*, *Dental Clinics of North America*, *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics*, *Clinical Implant Dentistry and Related Research*, *British Journal of Oral and Maxillofacial Surgery*, *International Journal of Periodontics and Restorative Dentistry*, *Journal of Periodontology*, *European Journal of Prosthodontics and Restorative Dentistry*, and *Journal of Oral Surgery*. In addition, other articles were identified from the reference lists of the articles found.

Search terms

The following search terms were selected: *atrophy*, *alveolar bone loss*, *fenestration*, *dehiscence*, *mandible*, *maxilla*, *edentulous jaw*, *edentulous maxilla*, *edentulous mandible*, *preprosthetic surgery*, *oral surgical procedure*, *alveolar ridge augmentation*, *oral implant*, *osseointegrated implant*, *dental*, *endosteal*, *endosseous*, *dental implantation*, *implant-supported*, *dental prosthesis*, *implant-supported dental prosthesis*, *guided bone regeneration*, *guided tissue regeneration*, *bone transplantation*, *graft*, *bone graft*, *humans*, *follow-up study*, *retrospective study*, *prospective study*, *comparative study*, *randomized clinical trial*, *morbidity*, *allograft*, *xenograft*, and *alloplastic*.

An electronic search was performed with two approaches, to obtain the widest possible span of results: a direct search via the Pubmed website system and an indirect search via a reference management software (Sente, Third Street Software). We limited the use of Boolean operators to the operator ''and'' to standardize the searches with the two different approaches: with this method, a larger number of searches using different combinations of keywords had to be performed, and the results were then filtered to eliminate double references and references not dealing with oral surgery, periodontology, and oral implant research (such as, craniofacial surgery surgery, orthopedic surgery, etc.).

Inclusion criteria

1. Any clinical investigation reporting on endosseous dental implants presenting with dehiscence or fenestration defects associated with the placement of implants (i.e. randomized clinical trials (RCTs), controlled clinical trials (CCts), cohort studies, case–control studies, and prospective and retrospective case series) was included;
2. Studies needed to report on a minimum of 10 consecutively treated patients;
3. Studies needed to report on implants with a minimum follow-up period of 12 months after the start of prosthetic loading;
4. Studies that included smokers were included; and
5. Studies utilizing only screw-type titanium endosseous implants including different types of surface modifications were included.

Exclusion criteria

1. Studies not meeting all inclusion criteria were excluded from the review;
2. Preclinical (animal) studies;
3. Studies in medically compromised patients, e.g., cancer, irradiated patients, were excluded;
4. Studies reporting on bone regeneration around implants placed in post-extractive sockets;
5. Studies reporting on bone regeneration around implants presenting with defects following periimplantitis;
6. Studies reporting on vertical and horizontal GBR procedures performed before implant placement;
7. Studies reporting on data from previous publications of the same groups of authors dealing with the same patients' samples were also excluded from the review.

Selection of studies

Titles derived from this broad search were independently screened by two investigators based on the inclusion criteria. Disagreements were resolved by discussion. Following this, abstracts of all titles agreed

on by both investigators were obtained and screened for meeting the inclusion criteria. The selected articles were then obtained in full text. If the title and the abstract did not provide sufficient information regarding the inclusion criteria, the full report was obtained as well. Again, disagreements were resolved by discussion.

Finally, the selection based on inclusion/exclusion criteria was made for the full-text articles.

Data extraction

Data retrieved were recorded on flow sheets including: (a) year of publication, (b) type of study, (c) details of participants including criteria of inclusion/exclusion, (d) details of the type of intervention, and (e) details of the outcomes reported.

Outcome measurements

The following treatment outcomes have been recorded for the included studies:

1. complication rate of the GBR procedure;
2. type of grafting material/type of membrane used for the correction of dehiscence/fenestration defects;
3. survival and success rates of implants placed in the augmented sites;
4. periimplant soft tissues changes in terms of variations of probing depth, modification of clinical attachment level, or exposure of the implant surface due to gingival recession.

Patients and methods

From a total of 1192 initially acquired titles, the exclusion of irrelevant studies performed by two independent reviewers reduced the amount of titles to a number of 115. After an abstract review of these titles, 41 potentially relevant publications remained and the reviewers proceeded to full-text evaluation. Among these, seven publications were included.

Exclusion of studies

The reasons for excluding studies ($n = 34$) after the full text was obtained were: (a) less than 10 patients treated; (b) follow-up of patients less than 12 months after the start of prosthetic loading; and (c) articles including patients presenting with an unclear study design or other types of defects. The list of excluded articles is reported in Table 1.

Inclusion of studies

Out of the seven articles selected, one was a controlled clinical study (including in the same patients both fenestrated/dehisced implants and implants completely surrounded by native bone (Zitzmann et al. 2001), four were prospective studies (Dahlin et al. 1995; Christensen et al. 2003; Blanco et al. 2005; De Boever & De Boever 2005), and two were retrospective studies (Lorenzoni et al. 2002; Juodzbalys et al. 2007) (Table 2).

Overall, 238 patients received 374 screw-shaped titanium implants: dehiscences/fenestrations created during implant placement were corrected with GBR procedures. Both non-resorbable (212 e-PTFE membranes) and resorbable (141 xenogenic collagen and 13 polylactic/polyglycolic acid membranes) membranes were used. Bone regeneration was obtained either by membranes alone or with the aid of various grafting materials, including AB, demineralized freeze-dried bone allograft (DFDB), and bovine bone mineral (BBM). However, it was often impossible to obtain separate data according to different grafting materials (see Table 2 for details).

Exposure of the implant surface at the end of an implant placement procedure, generally measured with periodontal probes, ranged from 1 to 12 mm in the coronal–apical direction. These data were reported in four out of seven articles (Dahlin et al. 1995; Blanco et al. 2005; De Boever & De Boever 2005; Juodzbalys et al. 2007), while in the remaining three articles no details were reported (Zitzmann et al. 2001; Lorenzoni et al. 2002; Christensen et al. 2003).

Prosthetic rehabilitation was started on average 5 months after implant placement (range: 3–6 months). Patients were rehabilitated with both fixed and removable implant-supported prostheses. Follow-up after the start of prosthetic loading of implants ranged from 12 to 114 months (Table 2).

Results

An uneventful healing of the GBR procedures with e-PTFE membranes (212 membranes placed) occurred in approximately 80% of the cases. In the remaining 20%, e-PTFE membranes underwent early exposure and/or infection, and at least 12 had to be removed before the planned time. However, these data cannot be reported precisely, because in one article (Lorenzoni et al. 2002), including both e-PTFE membranes and resorbable membranes, the distribution of exposures/infections according to the type of membrane was not clearly specified. Although better results (in terms of percentage of bone regeneration) were obtained in case of uneventful healing of the GBR procedure, an acceptable coverage of the initially exposed implant threads was also achieved in case of membrane exposure (63–100% coverage of the initial defect), with the majority of cases reporting complete or almost complete coverage of the initial defect. However, it is worth noting that only three (Dahlin et al. 1995; Blanco et al. 2005; De Boever & De Boever 2005) out of six articles dealing with e-PTFE membranes reported precise data on the clinical outcome of the regenerative procedure (evaluation of implant surface exposure before and after treatment with precise measurements).

As far as resorbable membranes are concerned, an uneventful healing of the GBR procedure with xenogenic collagen or polylactic–polyglycolic acid membranes (154 membranes) and a good coverage of initial defects occurred in the majority of cases (approximately 95%). However, it is worth noting that this percentage cannot be reported precisely for two reasons. The first one is that in one article (Lorenzoni et al. 2002), including both resorbable and non-resorbable membranes, the distribution of complications according to type membranes was not reported. The second one is that none out of four articles dealing with resorbable membranes reported precise data on the clinical outcome of the regenerative procedure (evaluation of implant surface exposure before and after treatment with precise measurements). Apparently, a lower complication rate was obtained with resorbable membranes and, according to authors' statements, at the time of reentry and start of prosthetic loading of implants, the majority of the previously exposed implant surface appeared to be covered by newly generated tissue.

During the follow-up period, one patient in one study (Dahlin et al. 1995) and nine

Table 1. **List of excluded studies**

Author	Journal/year	Cause of exclusion
Buser et al.	*Clinical Oral Implants Research*/1996	Insufficient patient sample, GBR before implant placement
Hammerle et al.	*Clinical Oral Implants Research*/2001	Insufficient follow-up
Mayfield et al.	*Clinical Oral Implants Research*/1997	Insufficient patient sample
Nemcovsky et al.	*International Journal of Oral & Maxillofacial Implants*/2000	Insufficient follow-up
Von Arx & Kurt	*Clinical Oral Implants Research*/1999	Insufficient follow-up and patient sample
Rominger	*Journal of Oral and Maxillofacial Surgery*/1994	Insufficient patient sample
Moses	*Clinical Oral Implants Research*/1995	Insufficient follow-up
Widmark et al.	*Clinical Implant Dentistry & Related Research*/2000	Insufficient follow-up
Becker et al.	*Clinical Implant Dentistry & Related Research*/1999	Implants placed immediately after tooth extraction
Veiss et al.	*International Journal of Periodontics and Restorative Dentistry*/2004	Insufficient follow-up
Janovic	*The International Journal of Oral & Maxillofacial Implants*/1992	Insufficient follow-up
Ofer et al.	*Clinical Oral Implants Research*/2005	Insufficient follow-up
Fugazzotto	*International Journal of Periodontics and Restorative Dentistry*/1997	Insufficient follow-up
Dahlin et al.	*Clinical Oral Implants Research*/1991	Insufficient patient sample
Jung et al.	*Clinical Oral Implant Research*/2003	Insufficient follow-up
Chen et al.	*Clinical Oral Implants Research*/2005	Implants placed immediately after tooth extraction
Nemcovsky et al.	*Journal of Periodontology*/2002	Insufficient follow-up
Christoph et al.	*Clinical Oral Implant Research*/2008	Insufficient follow-up
Rosen et al.	*Journal of Periodontology*/2001	Only 9 patients
Mayfield et al.	*Clinical Oral Implants Research*/1998	Only 7 patients
Mattout et al.	*Clinical Oral Implants Research*/1995	Insufficient follow-up
Sang-Hoon Park	*Journal of Periodontology*/2007	Insufficient follow-up
Zitzmann et al.	*The International Journal of Oral & Maxillofacial Implants*/1997	Insufficient follow-up
Simion et al.	*The International Journal of Oral & Maxillofacial Implants*/1997	Insufficient follow-up, insufficient patient sample
Jovanovic	*The International Journal of Oral & Maxillofacial Implants*/1992	Insufficient follow-up
Nevins et al.	*International Journal of Periodontology and Restorative Dentistry*/1998	Mixed data (dehiscence, post-extractive defects, etc.)
Shanaman et al.	*International Journal of Periodontology and Restorative Dentistry*/1994	Insufficient follow-up
Peleg et al.	*Journal of Oral and Maxillofacial Surgery*/2004	Insufficient follow-up
Geurs et al.	*Journal of Periodontology*/2008	No data on implants
De Boever & De Boever	*International Journal of Periodontics and Restorative Dentistry*/2003	Only 7 implants
Yukna et al.	*Compendium of Continuing Education in Dentistry*/2003	Post-extractive implants
Passi et al.	*General Dentistry*/1999	3 patients, no implant data after prosthetic loading
Majzoub et al.	*Clinical Oral Implants Research*/1999	7 patients, no implant data after prosthetic loading
Mayfield et al.	*Clinical Oral Implants Research*/1998	7 patients

patients in another (Zitzmann et al. 2001) dropped out of the studies.

As far as implant outcome is concerned, 16 implants were lost both before and after the start of prosthetic loading due to loss of osseointegration. The overall survival rate of implants, irrespective of the type of membrane and grafting materials, was 95.7% (range: 84.7–100%).

The success rate of implants according to well-defined criteria (Albrektsson et al. 1986) was reported in only two studies (Blanco et al. 2005; Juodzbalys et al. 2007), with a success rate of 96.1% and 90%, respectively.

For obtaining more information, we attempted to analyze the survival rates of implants according to (a) the type of membrane and (b) the type of grafting material (autogenous or non-autogenous).

However, it is worth noting that this analysis was limited by the fact that it was frequently difficult to correlate the survival rate of implants with the type of grafting material used in association with membranes: this is because different materials or mixtures of them were frequently used in the same article. It was also difficult to compare the clinical outcomes because: (a) many authors did not separate the outcomes of patients treated with resorbable and non-resorbable membranes; (b) the two types of membranes were used in combination with different grafting materials without separating data, thus introducing other variables that rendered a statistically significant comparison difficult or impossible; (c) the patient sample was frequently small; and (d) there is a paucity of controlled, split-mouth studies comparing different grafting materials and different membranes (see Table 2).

The survival rate of implants placed in conjunction with resorbable membranes ranged from 95.4% to 100%.

The survival rate of implants placed in conjunction with non-resorbable

Table 2. **Guided bone regeneration (GBR) at dehisced/fenestrated implant sites – characteristics of included studies**

Author (year)	Type of study	No. pts	Defect site	Type defect	Membrane type (no.)	Grafting material	GBR succ. %	No. implants	Drop-out pts/ implants	Removed implants	Follow-up (months)	Imp. surv. (%)	Imp. succ. (%)
Dahlin et al. (1995)	PS	45	Max/ mand	Deh/fen	e-PTFE (45)	None	89	55	1	6	24	84.7/95	N/D
Zitzmann et al. (2001)	CCT	75	Max/ mand	Deh	e-PTFE (41) XG (112)	BBM	N/D	153	9	8	55–70	92.6/95.4	N/D
Lorenzoni et al. (2002)	RS	41	Max/ mand	Deh	e-PTFE (64) PLPG (8)	AB/BBM/ none	57	72	0	0	36–60	100	N/D
Christensen et al. (2003)	PS	28	Max/ mand	Deh	e-PTFE (20) XG (9) PLPG (5)	BBM/AB/ none	100	32	0	0	36	100	N/D
Blanco et al. (2005)	PS	19	Max/ mand	Deh/fen	e-PTFE (26)	AB/DFDB/ none	88.5	26	0	1	60	96.1	96.1
De Boever & De Boever (2005)	PS	13	Max/ mand	Deh	e-PTFE (16)	BBM	81.3	16	0	1	12–114	93.8	N/D
Juodzbalys et al. (2007)	RS	17	Max/ mand	Deh	XG (20)	BBM	95	20	0	0	60	100	90
		238						374		16			

No. pts, number of patients treated; max, maxilla; mand, mandible; deh, dehiscence; fen, fenestration; e-PTFE, expanded polytetrafluorethilene; XG, xenogenic collagen; PLPG, polylactic–polyglycolic acid; BBM, bovine bone mineral; AB, autogenous bone; DFDB, demineralized freeze-dried bone; polylac, polylactic acid membrane; polyglyc, polyglycolic acid membrane; GBR succ., success rate of the GBR procedure; imp. surv., implant survival rate; imp. succ., implant success rate; N/D, no data.

Table 3. **Guided bone regeneration (GBR) at dehisced/fenestrated implant sites – GBR procedures details 2**

Author (year)	No. pts	Type of defect	Grafting material (no.)	GBR succ. %	Initial defect in mm (mean)	Defect at reentry in mm (mean)	Defect at reentry in case of exposure	Coverage gain of implants (%)	Implants removed	Imp. surv. (%)
Dahlin et al. (1995)	45	Fen/deh	None (45)	89	0–12	0–10 (1.2)		82	6	84.7–95
Zitzmann et al. (2001)	75	Fen/deh	BBM (153)	N/D	N/D	N/D	N/D	N/D	8	92.6–95.4
Lorenzoni et al. (2002)	41	Fen/deh	None (34) AB (16) BBM (12) AB + BBM (10)	57	N/D	N/D	N/D	N/D	0	100
Christensen et al. (2003)	28	Deh	None (21) AB (10) BBM (3)	100	N/D	N/D	N/D	N/D	0	100
Blanco et al. (2005)	19	6 fen 20 deh	DFDB (12) None (9) AB (5)	88.5	3–12 (6.2)	0–2 (0.2)	1–2 (1.6)	94.8	1	96.1
De Boever & De Boever (2005)	13	Deh	BBM (16)	81.3	3–9	0–2	N/D	63–100	1	93.8
Juodzbalys et al. (2007)	17	Deh	BBM (20)	95	4–10	N/D	N/D	95	0	100
	238									

No. pts, number of patients treated; deh, dehiscence; fen, fenestration; BBM, bovine bone mineral; AB, autogenous bone; DFDB, demineralized freeze-dried bone; GBR succ., success rate of the GBR procedure; N/D, no data; imp. surv., implant survival rate.

membranes ranged from 84.7% to 100%, while the survival rate of implants placed in conjunction with e-PTFE membranes and no grafting materials (116 implants) (Dahlin et al. 1995; Lorenzoni et al. 2002; Christensen et al. 2003; Blanco et al. 2005) ranged from 84.7% to 100%.

Conversely, it was impossible to determine the survival rate of implants placed in conjunction with e-PTFE membranes and autogenous bone, because the three articles related to this treatment modality (Lorenzoni et al. 2002; Christensen et al. 2003; Blanco et al. 2005) also used other membranes and other grafting materials without separating data related to the results.

The survival rate of implants placed in conjunction with e-PTFE membranes and BBM (Bioss®) (71 implants) (Zitzmann et al. 2001; Lorenzoni et al. 2002; De Boever & De Boever 2005) ranged from 93.8% to 100%, while the survival of implants in association with e-PTFE membranes and allograft was not evaluable, because the author did not separate data from other grafting materials (Blanco et al. 2005).

Table 4. **Guided bone regeneration (GBR) at dehisced/fenestrated implant sites – GBR procedures details 1**

Author (year)	No. pts	Type of defect	Membrane (no)	Membranes exposed	Membranes removed	GBR succ. %	Initial defect in mm (mean)	Defect at reentry in mm (mean)	Defect at reentry in case of exposure	Coverage gain of implants %	Implants removed	Imp. surv. %
Dahlin et al. (1995)	45	Fen/deh	e-PTFE (45)	6	6	89	0–12	0–10 (1.2)	N/D	82	6	84.7–95
Zitzmann et al. (2001)	75	Fen/deh	XC (112) e-PTFE (41)	0 1	0 1	N/D	N/D	N/D	N/D	N/D	8	92.6–95.4
Lorenzoni et al. (2002)	41	Fen/deh	e-PTFE (64) PLPG (8)	31	N/D	57	N/D	N/D	N/D	N/D	0	100
Christensen et al. (2003)	28	Deh	XC (9) e-PTFE (20) PLPG (5)	0	0	100	N/D	N/D	N/D	N/D	0	100
Blanco et al. (2005)	19	6 fen 20 deh	e-PTFE (26)	3	3	88.5	3–12 (6.2)	0–2 (0.2)	1–2 (1.6)	94.8	1	96.1
De Boever & De Boever (2005)	13	Deh	e-PTFE (16)	2	2	81.3	3–9	0–2	N/D	63–100	1	93.8
Juodzbalys et al. (2007)	17 238	Deh	XC (20)	1	0	95	1–12	N/D	N/D	95	0	100

No pts, number of patients treated; deh, dehiscence; fen, fenestration; e-PTFE, expanded polytetrafluorethilene; XG, xenogenic collagen; PLPG, polylactic–polyglycolic acid membrane; GBR succ., success rate of the GBR procedure; N/D, no data; imp. surv., implant survival rate.

The survival rate of implants placed in conjunction with xenogenic collagen membranes (Biogide®) in combination with BBM (Bioss®) (135 implants) (Zitzmann et al. 2001; Christensen et al. 2003; Juodzbalys et al. 2007) ranged from 95.4% to 100% (Tables 2–4).

The survival rate of implants placed in conjunction with xenogenic collagen membranes (Biogide®) as well as the use of polylactic–polyglycolic acid membranes alone, in combination with autogenous bone, allografts, or a combination of grafting materials, was not evaluable, because the sample was too small and/or such membranes were used with mixtures of different grafting materials (Lorenzoni et al. 2002; Christensen et al. 2003).

In terms of the stability of perimplant soft tissues around implants (variations in clinical attachment level and/or probing depth) initially affected by fenestrations/dehiscences and treated with GBR procedures, four (Zitzmann et al. 2001; Christensen et al. 2003; De Boever & De Boever 2005; Juodzbalys et al. 2007) out of seven articles reported data.

On average, no relevant modifications of probing depth and/or variation of clinical attachment level around implants were observed comparing measurements immediately after completion of prosthetic rehabilitation and at the end of the observation period (ranging from 1 to 9 years). These results seem to demonstrate that the stability and health of perimplant soft tissues may be expected after GBR procedures to correct dehiscences and fenestrations.

Discussion

Data reported in the literature seem to demonstrate that GBR procedures are a reliable means for treating dehiscences and fenestrations created during implant placement. Survival rates of implants placed in the sites augmented with GBR are consistent with those reported for implants placed into sites not necessitating bone augmentation procedures (Albrektsson et al. 1986; van Steenberghe 1989; van Steenberghe et al. 1990; Lekholm et al. 1994, 1999; Lindquist et al. 1996; Buser et al. 1997; Arvidson et al. 1998; Weber et al. 2000; Leonhardt et al. 2002). Moreover, as demonstrated by a controlled clinical study included in this review (Zitzmann et al. 2001), where implants were placed both in sites necessitating simultaneous GBR to correct fenestrations/dehiscences and in sites with enough bone to completely embed implants in the same sample of patients, the survival rates of implants in the two groups did not present significant differences (92% and 97%, respectively).

However, the analysis of available publications demonstrated, on average, a poor methodological quality, in particular, with regard to (a) dimension of samples, (b) clinical outcome according to the type of membrane and the type of grafting material used, (c) evaluation of stability over time of the augmented bone, (d) influence of GBR techniques on periimplant soft tissues health, and (e) implant outcome according to well-defined success criteria.

Therefore, the following issues require a more accurate evaluation in future publications and the following questions should be addressed:

(a) Which is the more effective membrane and the more effective grafting material?
(b) Are augmentation procedures used for the correction of dehiscence/fenestration defects really necessary and do they have any effect on the long-term survival/success of implants?
(c) Which is the influence of GBR procedures in the stability of periimplant soft tissues around implants initially affected by fenestration/dehiscence defects?

(a) Which is the more effective membrane and the more effective grafting material?

In one article (Dahlin et al. 1995) including 45 patients and 55 implants, defects were treated with the use of e-PTFE membranes only. Premature membrane exposure due to soft tissue dehiscence occurred in six of 44 patients followed (13.6% membrane exposure) (one patient dropped out early after surgery) and all exposed membranes were removed. The authors stated that successful coverage of exposed

implant threads can be obtained with membranes without the aid of any grafting material. They also concluded that, despite a 13.6% membrane exposure rate, a significant bone regeneration was obtained (82% of initial implant surface was covered at reentry), including both early exposed membranes and normally healed membranes, with no statistically significant differences between the two groups. Four implants were removed before loading and two after loading. The mean survival rate of implants was 88.9% (84.7% in the maxilla and 95% in the mandible). However, the authors did not specify whether implants were lost in the patients presenting with membrane exposure.

In one article (Zitzmann et al. 2001), including 75 patients and 153 implants, defects were treated with the use of e-PTFE membranes (Gore-tex®) (41 implants) or collagen membranes (Biogide®) (112 implants) in association with BBM (Bio-ss®). All patients also had at least one implant that was entirely surrounded by native bone and served as the control (112 implants). The survival rate of implants covered with Biogide® membranes was 95%, the survival rate of implants covered with Gore-tex® membranes was 92.6%, while the survival of the control group was 97.3%.

Conclusions by the authors were as follows: (a) the long-term survival of implants with and without dehiscences/fenestrations was not statistically different and (b) marginal bone-level changes evaluated with intraoral radiographs were higher in those patients treated with GBR (mean: 2.2 mm) as compared with the control implants with no regeneration (mean: 1.7 mm), after 2 years of follow-up. The authors also concluded that GBR is indicated when a dehiscence is larger than 2 mm in the vertical dimension. They also concluded that gingival recession was more strongly associated with the type of implant restoration than with the application of GBR treatment.

In one article (Lorenzoni et al. 2002), including 41 patients and 72 implants, e-PTFE membranes (Gore-tex®) (47 implants), titanium-reinforced e-PTFE membranes (17 implants) or PLPGA membranes (Resolut®) (eight implants) were used. Membranes were used either alone (34 implants) or in association with autogenous bone, BBM (BioOss®), or as a combination of the two. The authors, however, did not report data on initial defect extension and percentage of implant coverage at the time of reentry. Thirty-one implants underwent premature membrane exposure, but it was not reported as to which membranes became exposed more frequently, although they observed a significantly higher risk of exposure/dehiscence/infection with e-PTFE membranes and also a higher number of soft tissue problems during healing. The authors observed more bone resorption in patients with premature membrane exposure, but no statistically significant difference between the two membranes as far as the survival rate of implants was concerned. They reported an overall survival rate of implants of 100%. However, it is really difficult to draw any significant conclusion from such a study in which three different membranes and three different grafting materials were used.

In another article (Christensen et al. 2003), including 28 patients and 32 implants, three different membranes (e-PTFE, xenogenic collagen membrane, and polylactic–polyglycolic acid membrane), both without grafting materials and with autogenous bone or BBM, were used. The authors reported a 100% success rate of the GBR procedure, with 72% of the cases with stable bone around implants, and a 100% survival rate of implants. However, it is very difficult to evaluate which membrane was more effective, due to the large variety of materials used in a small number of patients.

In one article (Blanco et al. 2005), including 19 patients and 26 implants, e-PTFE membranes were used either alone (nine implants), in association with autogenous bone (five implants), or in association with a DFDBA allograft. Early membrane exposure occurred in 11.5% of the patients (three cases).

In the group with membrane exposure, an incomplete coverage of the initial defect was obtained, although with acceptable results (initial mean vertical exposure of buccal surface of implants: 8.3 mm; at the time of reentry: 1.6 mm).

Conversely, in the group without membrane exposure an almost complete coverage of the initial defect was obtained (initial mean exposure of implants: 6.2 mm; at the time of reentry: 0.2mm).

The overall survival rate of implants was 96.1% (one implant lost in the group of patients who healed normally after the augmentation procedure).

In another article (De Boever & De Boever 2005), including 13 patients and 16 implants, e-PTFE membranes (Gore-tex®) were used in association with BBM (BioOss®). Two membranes were removed earlier than expected (12.5%), due to exposure/infection. Coverage of the initial defect ranged from 63% to 100%, with the majority of cases presenting with more than 90% of the initially exposed implant surface covered (initial exposure of implants: 3–9 mm; at the time of reentry: 0–2 mm).

The overall survival rate of implants was 93.8% (one implant lost).

In the last article (Juodzbalys et al. 2007), including 17 patients and 20 implants, xenogenic collagen membranes (Biogide®) were used in association with BBM.

One membrane underwent early exposure but was not removed. Although the measurement of initial exposure of implants in the vertical dimension was reported (ranging from 1 to 12 mm), no data of bone gain at the time of abutment connection were reported, but only radiographic variations of bone-to-implant contact mesial and distal to each implant. The authors just stated that resorbable membranes need very frequently autografts or other grafting materials as a scaffold for the membrane and that BBM appeared the more appropriate to be grafting material.

The overall survival rate of implants at the end of the observation period was 100%.

The authors stated that resorbable membranes need very frequently autografts or other grafting materials as a scaffold for the membrane. BioOss® appeared to be the more appropriate grafting material (see Tables 2–4).

(b) Are augmentation procedures used for the correction of dehiscence/fenestrations really necessary and do they have any effect on the long-term survival/success of implants?

Ideally, to address this question, randomized clinical trials that compare treatment with GBR vs. non-treatment of fenestrations/dehiscences should be performed.

However, out of the seven selected articles, none presented the aforementioned characteristics.

Only one article (Zitzmann et al. 2001) was a controlled split-mouth study, including 75 patients presenting with dehiscences at the time of implant placement (153 implants), but implants presenting with dehiscences were only compared with implants without any defect. More in detail, patients presenting dehiscences or fenestrations at the time of implant placement were treated with e-PTFE membranes or xenogenic collagen membranes (BioGide®) in association with BBM (BioOss®). All patients also had at least one implant that was entirely surrounded by native bone and served as the control (112 implants). The survival rate of implants covered with BioGide® membranes was 95%, the survival rate of implants covered with Gore-tex® membranes was 92.6%, while the survival of the control group was 97.3%.

The conclusions by the authors were as follows: (a) the long-term survival of implants with dehiscences/fenestrations was similar to that obtained for implants without dehiscences and (b) marginal bone-level changes evaluated with intraoral radiographs were higher in those patients treated with GBR (mean: 2.2 mm) as compared with the control implants with no regeneration (mean: 1.7 mm), after 2 years of follow-up. The authors also concluded that because a marginal bone-level change between 1.7 and 2.2 mm can be expected after 5 years of follow-up, it may be concluded that GBR is indeed indicated when the initial effect is larger than 2 mm in the vertical dimension.

This article, however, was only able to demonstrate that dehisced implants, if properly treated with grafting materials and membranes, may lead to a survival rate of implants similar to that obtained in implants completely embedded in native bone, but it was not designed to demonstrate whether GBR is really needed in case of fenestrations/dehiscences. To obtain such an information, as already underlined, randomized clinical trials comparing treatment vs. no treatment of dehiscences should be performed. To the authors' knowledge, nothing has been published yet.

(c) Which is the influence of GBR procedures on the stability of periimplant soft tissues of implants initially affected by fenestration/dehiscence defects?

In terms of the stability of periimplant soft tissues (variations in clinical attachment level and/or probing depth) around implants initially affected by fenestrations/dehiscences and treated with GBR procedures, four articles (Zitzmann et al. 2001; Christensen et al. 2003; De Boever & De Boever 2005; Juodzbalys et al. 2007) out of seven reported data.

On average, no relevant modifications of probing depth and/or variation of clinical attachment level around implants were observed comparing measurements immediately after completion of prosthetic rehabilitation and the end of the observation period (ranging from 1 to 10 years). These results seem to demonstrate that stability and health of periimplant soft tissues may be expected after GBR procedures to correct dehiscences and fenestrations.

Generally speaking, the main limitation encountered in this review is that there is a paucity of data regarding the efficacy and effectiveness of augmentation procedures with GBR techniques in case of fenestrations or dehiscences associated with implant placement in moderately atrophic partially or totally edentulous ridges.

More in detail, the effectiveness of GBR procedures around dehisced/fenestrated implants has been clinically controlled only at the time of re-entry for membrane removal and/or of abutment connection and start of prosthetic rehabilitation. Moreover, precise data regarding the initial situation (in terms of the exposed surface of implants, generally expressed in millimeters in the coronal/apical direction) and the situation at the time of re-entry have been reported in only three out of six articles dealing with non-resorbable membranes and in none of the articles (4) dealing with resorbable membranes.

Conversely, during the follow-up period, controls were performed only by periimplant soft tissues parameters (four out of seven studies) or by means of intraoral periapical radiographs (all seven articles). This type of evaluation presents a relevant limitation: intraoral X-rays can only monitor bone-to-implant contact variations along the vertical dimension, mesial and distal to each implant, but they are not able to show any variation of the regenerated tissue on the buccal aspects of implants, which is the main factor to be observed time after the GBR procedures.

The only means available should be computed tomography or re-entry. The first option, however, is costly both economically and biologically and difficult to be proposed as a routine method for measuring stability over time of the regenerated bone. The second option is also difficult to apply due to the difficulty in justifying an invasive manoeuvre to control results.

However, it must be underlined that, even if the role of GBR in the improvement of the survival rate of implants placed in the presence of dehiscence-type defects is still questionable, tissue regeneration in dehiscence-type defects associated with the placement of implants may play an important role as far as the esthetic outcome of the rehabilitation is concerned. There are mainly three esthetic complications that can arise in cases where the exposed implant surface is left uncovered (a) soft tissue recession in the buccal aspect, leading to exposure of implant threads to the oral environment; (b) 'gray areas' on soft tissues overlying the dehiscence, especially in patients with thin periimplant tissues, due to the transparency of the mucosa; and (c) flattened aspect of the alveolar ridge in the buccal side, due to the non-regenerated horizontal defect (loss of the radicular eminence).

Conclusion

Despite the recommendations that have already appeared in previous review papers (Chiapasco et al. 2006; Esposito et al. 2008), which strongly suggested the need for better designed studies according to Consolidated Standards of Reporting Trials (CONSORT) (Moher et al. 2001), the main limitation encountered in this literature review has been the overall poor methodological quality of the published articles: this aspect may reduce the possibility of drawing significant conclusions.

Within the limits of the included studies and on the basis of the collected data, it can be concluded that:

1. There is not enough evidence demonstrating the need for covering fenestration/dehiscences in order to guarantee a better outcome as far as the long-term survival of implants is concerned.

Although not included in this review as it did not fulfilling our inclusion criteria, it is worth noting that Dahlin et al. (1991), in a historical split-mouth study related to the treatment of fenestrated implants (machined titanium implants ad modum Branemark) with or without non-resorbable e-PTFE membranes, demonstrated that there was a significant bone gain in the group treated with GBR when compared with the untreated group, but no differences in implant survival were found. This study, despite demonstrating that new bone can be generated around fenestrated implants with the aid of semipermeable barriers, failed, however, to demonstrate that bone regenerated around fenestrated implants could have any significant effect on implant survival.

2. Both resorbable and non-resorbable membranes showed the ability to promote bone coverage of initial implant surface exposure. However, non-resorbable membranes were susceptible to higher complication rates as compared with resorbable membranes (20% and 5%, respectively);
3. Non-resorbable membranes showed the ability to promote bone regeneration on a dehisced implant surface also without graft materials;
4. Resorbable membranes can promote similar amounts of bone regeneration, provided that grafting materials are placed between the exposed implant surface and the membrane;
5. Autogenous bone has not demonstrated to promote better bone regeneration as compared with non-autogenous grafting materials. As autogenous bone exposes patients to increased morbidity, there is no evidence that demonstrates the superiority of using such a material;
6. Although the majority of selected articles reported almost complete coverage of initial implant surface exposure, this finding was controlled and measured at the time of re-entry for removing non-resorbable membranes and/or for the start of prosthetic rehabilitation. Conversely, there are no data demonstrating the stability over time of the regenerated bone, but only indirect data. These are mainly represented by implant stability over time, implant survival and radiographic controls. These latter, however, can only demonstrate vertical variations of bone-to-implant contact mesial and distal to each implant, but are not able to provide any significant information on bone variation on the buccal site, which is the main factor to be observed after the GBR procedures. To partially overcome the limits of intraoral radiographs, variations of clinical attachment level, and not just only probing depth measurements, should be routinely included in such studies. Although an unmodified clinical attachment level during the follow-up period might not be an absolute indicator of stability of the augmentation obtained on dehisced/fenestrated implants, this parameter can at least demonstrate absence of gingival recession due to complete resorption of the augmented bone;
7. Finally, it must be underlined that, even if the role of GBR in the improvement of survival rate of implants placed in the presence of dehiscence-type defects is still questionable, tissue regeneration in dehiscence-type defects associated with the placement of implants may play an important role as far as the esthetic outcome of the rehabilitation is concerned. There are mainly three esthetic complications that can arise in cases where the exposed implant surface is left uncovered (a) soft tissue recession in the buccal aspect, leading to exposure of implant threads to the oral environment; (b) 'gray areas' on soft tissues overlying the dehiscence, especially in patients with thin periimplant tissues, due to the transparency of the mucosa; and (c) flattened aspect of the alveolar ridge in the buccal side, due to the non-regenerated horizontal defect (loss of the radicular eminence).

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