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Review Paper
Dental Implants

Success rate of dental implants inserted in horizontal and vertical guided bone regenerated areas: a systematic review

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Abstract. This study assessed the success rate of implants placed in horizontal and vertical guided bone regenerated areas. A systematic review was carried out of all prospective and retrospective studies, involving at least five consecutively treated patients, that analysed the success rate of implants placed simultaneously or as second surgery following ridge augmentation by means of a guided bone regeneration (GBR) technique. Studies reporting only the survival rate of implants and studies with a post-loading follow up less than 6 months were excluded. From 323 potentially relevant studies, 32 full text publications were screened and 8 were identified as fulfilling the inclusion criteria. The success rate of implants placed in GBR augmented ridges ranged from 61.5% to 100%; all studies, apart from three, reported a success rate higher than 90% (range 90–100%). The data obtained demonstrated that GBR is a predictable technique that allows the placement of implants in atrophic areas. Despite that, studies with well-defined implant success criteria after a longer follow-up are required.

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Dental rehabilitation of partially or totally edentulous patients with oral implants is a valid method for restoring oral aesthetics and function with predictable results.[1–9] A minimum amount of bone width and height is essential for the successful placement of implants.[5,10] Unfavourable local conditions, due to atrophy, trauma and periodontal disease, may provide insufficient bone volume or an unfavourable interarch relationship, which does not allow correct and a prosthodontically guided positioning of dental implants.[10]

Many techniques have been developed to reconstruct deficient alveolar jaws for the placement of dental implants performed either in combination or in second stage surgery after a period of healing.[11] The development of the guided bone regeneration (GBR) technique started in the late 1980s with a series of experimental studies. Then clinicians started to use barrier membranes in implant patients for various clinical indications.[12,13]

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GBR is based on the concept of using a resorbable or a non-resorbable barrier membrane to stabilize the blood clot and to create a space into which cells originating from bone tissue can grow without the interference of the faster proliferating soft tissue cells.[11–13] GBR allows the positioning of dental implants in atrophic ridges, which otherwise would not be possible; survival rates range from 91.7 to 100%.[14]

The survival rates of implants placed in augmented sites with GBR are reported in many publications,[14] but there are few data about the success rate of dental implants placed in those areas, according to universally established criteria. This may represent a limit in evaluating the reliability of the GBR technique, because a high implant survival rate may not correspond to a high GBR success rate bearing in mind that an implant can remain stable and osseointegrated even if the total amount of regenerated tissue has been resorbed after the GBR procedure.

The present systematic review was carried out to analyse all publications reporting the success rate of implants placed in vertically and horizontally augmented areas using the GBR technique. The specific question addressed was 'In patients treated with horizontal and/or vertical GBR, what are the clinical outcomes, in terms of implant success rate after a minimum 6 month follow-up period?'

Material and methods

Inclusion and exclusion criteria were defined by the authors, before the start of the study.

The inclusion criteria were as follows. All studies published in English language, based on human subjects, involving more than five consecutively treated patients were considered. All studies analysing the success rate of endosseus implants placed in jaws augmented by means of horizontal and vertical GBR were included. Studies had to report on implants with at least 6 months of loading, because this allows the observation of biological complications during function rather than early implant failures. Studies had to show data allowing the computation of the success rate by means of survival analysis. Studies on smokers were included. Studies on healthy patients were included.

The exclusion criteria were as follows. Publications that reported the same data as later publications by the same authors and systematic reviews were not considered. Studies reporting the results of GBR not followed by implant placement and/or with a post-loading follow-up period less than 6 months, were excluded. Studies reporting only the survival rate of implants or with not enough specified success criteria were not included. Studies on medically compromised patients were excluded. Studies about major maxillofacial reconstructions following big tissue resections in case of tumours as well as bone defects related to congenital malformations (such as cleft lip and palate or major craniofacial malformations), were excluded. Studies describing socket preservation techniques or the treatment of periimplantitis were excluded.

Types of interventions

GBR to reconstruct vertical and/or horizontal defects, was considered. According to the principle of GBR, a protected space is created with a resorbable or non-resorbable barrier membrane over the area to be augmented, to stabilize the blood clot and to exclude soft tissue penetration.[15,16] Bone regeneration may be obtained by means of membranes alone, or with the aid of various grafting materials, such as autogenous bone; demineralized or mineralized freeze-dried bone allografts, hydroxyapatite, bovine bone mineral, tricalcium phosphate or mixtures of different materials.[10]

Outcome measures

Implant success, as a combination of the success criteria previously defined by Albrektsson et al.,[2] and adapted by Buser et al.,[12,17] as well as Karoussis et al.,[18] was considered. It included: absence of mobility[12]; absence of persistent subjective complaints (pain, foreign body sensation and/or dysaesthesia)[12]; absence of recurrent peri-implant infection with suppuration[12]; absence of a continuous radiolucency around the implant[12]; no pocket probing depth (PPD) >5 mm[19,20]; and no PPD $\geq$ 5 mm and bleeding on probing (BOP).[19] During the first year, 1.5 mm of vertical bone resorption was accepted. After the first year of insertion, the annual vertical bone loss should not exceed 0.2 mm (mesially or distally).[2,21]

Even though not all the studies adopted the same success criteria, they were always well specified in the publications included.

Search strategy

The search strategy involved searching electronic databases (MEDLINE, EMBASE, and COCHRANE LIBRARY) and was supplemented by cross-checking the bibliographies of relevant review articles, up to January 2010.

The following combination of words was used: (success[All Fields] AND rate[All Fields]) OR (''dental implants'' [MeSH Terms] OR #''dental''[All Fields] AND ''implants''[All Fields]# OR ''dental implants''[All Fields]) OR #osseointegrated[All Fields] AND implants[All Fields]# OR ##''mouth''[MeSH Terms] OR ''mouth''[All Fields] OR ''oral''[All Fields]# AND implants[All Fields]# OR #implant[All Fields] AND supported[All Fields] AND #''prosthesis implantation''[MeSH Terms] OR #''prosthesis''[All Fields] AND ''implantation''[All Fields]# OR ''prosthesis implantation''[All Fields] OR ''prosthesis''[All Fields] OR ''prostheses and implants'' [MeSH Terms] OR #''prostheses''[All Fields] AND ''implants''[All Fields]# OR ''prostheses and implants''[All Fields]## OR #transmucosal[All Fields] AND implants[All Fields]# OR one-stage[All Fields] OR two-stages[All Fields] OR #immediate[All Fields] AND placement[All Fields]# OR #delayed[All Fields] AND placement[All Fields]#) AND #''alveolar ridge augmentation'' [MeSH Terms] OR (''alveolar''[All Fields] AND ''ridge''[All Fields] AND ''augmentation''[All Fields]) OR ''alveolar ridge augmentation''[All Fields]) OR (vertical[All Fields] AND ridge[All Fields] AND augmentation[All Fields]) OR (augmented[All Fields] AND ridges[All Fields]) OR (''bone regeneration'' [MeSH Terms] OR (''bone''[All Fields] AND ''regeneration''[All Fields]) OR ''bone regeneration''[All Fields]) OR (''bone substitutes''[MeSH Terms] OR (''bone''[All Fields] AND ''substitutes''[All Fields]) OR ''bone substitutes''[All Fields]) OR (autogenous[All Fields] AND (''bone and bones''[MeSH Terms] OR (''bone''[All Fields] AND ''bones''[All Fields]) OR ''bone and bones''[All Fields] OR ''bone''[All Fields]) AND (''transplantation''[Subheading] OR ''transplantation''[All Fields] OR ''grafts''[All Fields] OR ''transplants''[MeSH Terms] OR ''transplants''[All Fields])) OR (''inlays'' [MeSH Terms] OR ''inlays''[All Fields] OR ''onlay''[All Fields]) OR ((''inlays'' [MeSH Terms] OR ''inlays''[All Fields] OR ''onlay''[All Fields]) AND (''bone and bones''[MeSH Terms] OR (''bone'' [All Fields] AND ''bones''[All Fields]) OR ''bone and bones''[All Fields] OR ''bone''[All Fields]) AND (''transplantation''[Subheading] OR ''transplantation''[All Fields] OR ''grafts''[All Fields] OR ''transplants''[MeSH Terms] OR

''transplants''[All Fields])) OR (''bone transplantation''[MeSH Terms] OR (''bone''[All Fields] AND ''transplantation''[All Fields]) OR ''bone transplantation''[All Fields]) OR (''transplantation, homologous''[MeSH Terms] OR (''transplantation''[All Fields] AND ''homologous''[All Fields]) OR ''homologous transplantation''[All Fields] OR (''homologous''[All Fields] AND ''transplantation''[All Fields])) OR ''transplantation, homologous''[MeSH Terms] OR (''transplantation''[All Fields] AND ''homologous''[All Fields]) OR ''homologous transplantation''[All Fields] AND %5[All Fields].

Studies published in the English language were included.

Selection criteria and data extraction

The search resulted in a great number of published studies about the topic, so a three stage screening process was performed by two independent reviewers (A.M. and M.C.) and disagreement between the two reviewers was resolved after additional discussion.

All the titles were screened to eliminate irrelevant publications, review articles and animal studies. All abstracts of publications selected during the first screening were analysed, excluding studies based on the number of patients, the intervention and the outcome characteristics. Through analysis of the whole selected full texts, the study eligibility was based on the predetermined inclusion and exclusion criteria. A table with data from all the included studies was created and the results were discussed.

Quality assessment

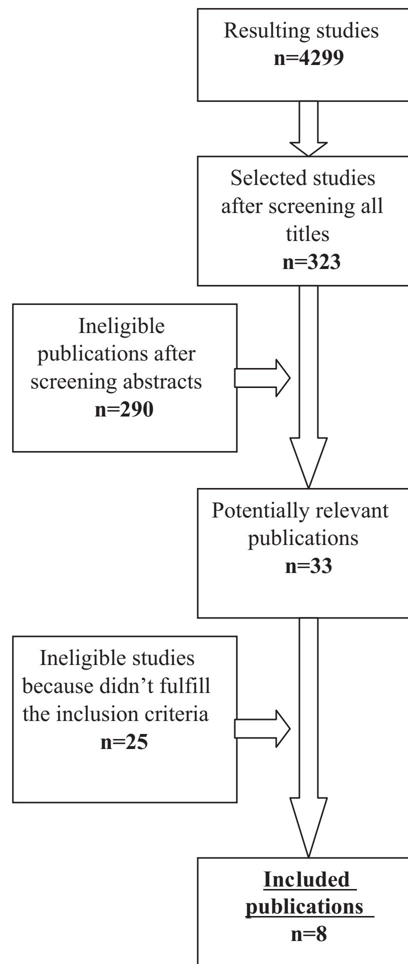
Assessment of methodological study quality was performed combining the proposed criteria by MOOSE statement,[22] STROBE statement,[23,24] PRISMA.[25,26]

When random selection in the population, defined inclusion/exclusion criteria, report of losses to follow-up, validated measurements and statistical analysis were reported the study was classed as at a low risk of bias. When missing one of these five criteria, the study was classed as having a moderate potential risk of bias. There was a high potential risk of bias if the study was missing two or more of these criteria.

Results

The search resulted in 4299 titles. Following the first stage of screening, 323 potentially relevant studies were identified.

Table 1. Flow of studies through the review.



After the second stage screening, 32 full text publications were obtained and analysed, resulting in 8 articles fulfilling the inclusion criteria (Table 1).

The review included prospective and retrospective cohort studies reporting data about the success rate of implants placed in areas augmented by vertical and/or horizontal GBR procedures. Owing to the significant heterogeneity of the outcome measures, meta-analysis was not performed and the synthesis of the data was determined from the evidence table alone (Table 2).

Patients

Four[16,27,29,30] of eight studies involved fewer than 17 patients. The other studies included 40,[5] 49,[31] 82[32] and 319[28] patients. The age of patients was not always reported but considering the studies in which this parameter is described,[16,27,28,30–32] a mean age of 46 years can be calculated.

Implants

The number of implants placed in areas (maxilla or mandible) augmented by GBR ranged from 14 to 85 in six studies.[5,16,27,29,30,32] The remaining two studies reported 423[28] and 123[31] positioned implants.

The minimum post-loading follow up was 1 year.[27] Four studies[5,16,28,30] reported follow-up values of 5 or more years.

Implant survival and success rate

The success rate of implants placed in GBR augmented ridges ranged from 61.5% to 100%. All the studies, except three,[27,29,30] reported a success rate higher than 90% (range 90–100%).

The survival rate of implants, was reported in 6 studies[5,16,27,29,31,32] to range from 93.75% to 100%. One study[27] reported a survival rate lower than 99.2%.

Table 2. Success rate of implants placed in GBR augmented sites. Characteristics of the studies.

Author	Type of study	Year	City	Type of augm.	N. patients	Mean age	Implants	Area of implants	Post-loading follow-up	Cumulative success rate of implants	Cumulative survival rate of implants
1. F. Llambés[27]	c.s.	2007	Valencia (Spain)	Vertical gbr	11	48	32 imm.	Mandible	1 year	75%	93.75%
2. G. Juodzbalys[16]	c.s.	2007	Kaunas (Lithuania)	Vertical gbr	17	39.6	20 imm.	–	1 year	90%	100%
3. P.A. Fugazzotto[28]	r.s.	2005	Milton (Massachussets)	Vertical and Horizontal gbr	319	49	423 imm/del	215 maxilla 208 mand.	7 years 11 years	98.30% 97.40%	–
4. M. Chiapasco[29]	rct	2004	Milan (Italy)	Vertical gbr	11	–	25 (13 imm; 12 del)	10 maxilla 15 mand.	1 year 2 year 3 year	84.6% (imm) 83.3% (del) 76.9% (imm) 83.3% (del) 61.5% (imm) 75% (del)	100% (imm) 100% (del) 100% (imm) 100% (del) 100% (imm) 100% (del)
5. D. Buser[5]	c.s	2002	Berne (Switzerland)	Horizontal gbr	40	–	61 del.	–	1 year 5 years	100% 98.30%	100% 100%
6. G. Brunel[30]	c.s.	2001	Toulouse (France)	Gbr	14	48	14 del.	13 maxilla 1 mand.	1 year 2 years 3 years 4 years 5 years 6 years 7 years	100% 100% 100% 86% 86% 86% 86%	– – – – – – –
7. M. Simion[31]	ccs	2001	Parma (Italy)	Vertical gbr	49	50.4	123 (120 imm; 3 del)	–	1 year 2 years 3 years 4 years 5 years	97.50% 97.50% 97.50% 97.50% 97.50%	99.20% 99.20% 99.20% 99.20% 99.20%
8. M. Lorenzoni[32]	c.s.	1999	Graz (Austria)	Gbr	82	21–61	85	39 maxilla 46 mand.	1 year 2 years	100% 100%	100% 100%

c.s. = case series; rct = randomized controlled clinical trial; cct = controlled clinical trial imm. = immediate; del. = delayed; r.s. = retrospective study.

Table 3. Quality assessment of the included studies.

Study quality criteria	Llambés et al.[27] 2007	Juodzbalys et al.[16] 2007	Fugazzotto[28] 2005	Chiapasco et al.[29] 2004	Buser et al.[5] 2002	Brunel et al.[30] 2001	Simion et al.[31] 2001	Lorenzoni et al.[32] 1999
Random selection in population	No	No	No	Yes	No	Yes	?	No
Defined inclusion/exclusion criteria	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Reported loss to follow-up	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Validated measurements	No	Yes	No	Yes	Yes	No	Yes	Yes
Statistical analysis	No	Yes	No	Yes	Yes	No	Yes	?
Estimated potential risk of bias	High	Moderate	High	Low	Moderate	High	Moderate	High

Quality assessment

Six of the eight studies performed between 1999 and 2007 were case series; they were prospective studies except for one which was a retrospective study.[28] One study[29] was a randomized controlled clinical trial, and one[31] was a retrospective controlled clinical trial. The estimated risk of bias is considered to be high for four studies,[27,28,30,32] moderate for three[5,16,31] and low for one[29] (Table 3).

Discussion

Analysis of the literature reveals that there are not many studies fulfilling the inclusion criteria of the present systematic review because many studies do not adopt well defined success criteria for dental implants placed in GBR regenerated areas. That is why the present systematic review only includes 8 studies.

Data reported in the literature seem to demonstrate that GBR procedures are a reliable means for augmenting bone in cases of vertical and/or horizontal defects in partially edentulous patients. These data suggest that GBR should be considered a reliable technique for obtaining bone formation and placing dental implants in cases in which it would otherwise not be possible.

The analysis of changes in ridge dimensions over time reported in the included studies confirm these findings, even if it is not possible to report a mean of bone gain/resorption values. The lack of proper standardized radiographs and the lack of well-performed radiographs or clinical measurements taken immediately after implant placement led to the possibility of error for the evaluation of the outcomes. The studies adopt different measurements taken at different times, either reporting augmented bone resorption over time, or the values of required bone volumes, or the values of bone gain. From the studies included, it is also difficult to identify a clear effect of the different barrier membranes and/or the different biomaterials. Considering the great variation in the techniques and materials used for GBR in the included studies and the various methodological aspects of each study, it is not possible to obtain unique significant data about the success of GBR.

Data about the success of GBR should be obtained by analysis of the success rate of implants placed in these augmented areas. To focus on the question of the present systematic review, it is important to define the difference between the concepts of survival and success rate. Sometimes, implants that could be considered 'survived' do not satisfy the essential criteria that define the success rate. The survival rate of an implant is defined as its presence in the bone into the mouth. Van Steenberghe defined survival rate as 'the proportion of implants still in place in a specific time, even if they do not have any function'.[3] An implant that is not in function or an implant with significant bone loss or with signs of radiolucency and/or inflammation is a survived implant. This may represent a limit in evaluating the reliability of GBR, because a high implant survival rate may not correspond to success of the GBR technique, considering that an implant can remain stable and osseointegrated even if the total amount of regenerated tissue after the GBR procedure has been resorbed.

For these reasons, in this review, only studies reporting well-defined implant success criteria were included. Since implant success is a time-sensitive variable, only studies showing data that allowed the determination of survival analysis were included. Such analysis has shown how the success rate decreased over the time.

The outcomes from the present review suggest that GBR is a reasonably reliable ridge augmentation technique, that allows a high implant success rate. Owing to the significant heterogeneity of the parameters considered in these studies, meta-analysis was not performed and the synthesis of the data was determined from the evidence table alone (Table 2).

The great variability of the success rate of dental implants (when reported) placed in GBR augmented sites may suggest that the outcome of this technique could depend only on the abilities of each surgeon.

The analysis of available publications demonstrated, on average, the lack of universally established implant success criteria. Even when these criteria were satisfied, a control group was often absent and the post-loading follow up was often too short.

As demonstrated by the analysis of quality assessment of studies included in the present review (Table 3), four of the eight studies are considered to be at a high risk of bias, three at a moderate risk, and one as at low risk. This observation underlines the importance of producing well conducted-studies to obtain strong evidence based results. These considerations limit the results of this systematic review, but focus on the necessity in literature studies of reporting well-defined implant success rate criteria, with at least 5 years of post loading follow up, and (if possible) involving a control group.

In conclusion, data demonstrate that GBR is a predictable technique that allows the placement of implants in atrophic areas. Despite that, studies with well-defined implant success criteria after a longer follow-up are required.

Competing interests

None declared.

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None.

Ethical approval

Not required.

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