

SUPPLEMENT ARTICLE

Regeneration of alveolar ridge defects. Consensus report of group 4 of the 15th European Workshop on Periodontology on Bone Regeneration

Søren Jepsen¹  | Frank Schwarz²  | Luca Cordaro³ | Jan Derks⁴  |
 Christoph H. F. Hämmeler⁵ | Lisa J. Heitz-Mayfield⁶ | Federico Hernández-Alfaro⁷ |
 Henny J. A. Meijer⁸ | Nadja Naenni⁵  | Alberto Ortiz-Vigón⁹ | Bjarni Pjetursson¹⁰ |
 Gerry M. Raghoobar¹¹  | Stefan Renvert¹²  | Isabella Rocchietta¹³ |
 Mario Rocuzzo¹⁴ | Ignacio Sanz-Sánchez⁹  | Massimo Simion¹⁵ |
 Cristiano Tomasi⁴  | Leonardo Trombelli¹⁶ | Istvan Urban¹⁷

¹Department of Periodontology, Operative and Preventive Dentistry, University of Bonn, Bonn, Germany

²Department of Oral Surgery and Implantology, Carolinum, Johann Wolfgang Goethe-University, Frankfurt, Germany

³Department of Periodontics and Prosthodontics, Policlinico Umberto I, Eastman Dental Hospital, Rome, Italy

⁴Department of Periodontology, Institute of Odontology, The Sahlgrenska Academy at University of Gothenburg, Gothenburg, Sweden

⁵Clinic of Fixed and Removable Prosthodontics and Dental Material Science, University of Zürich, Zurich, Switzerland

⁶International Research Collaborative - Oral Health and Equity, School of Anatomy, Physiology and Human Biology, University of Western Australia, Perth, Western Australia, Australia

⁷Department of Oral and Maxillofacial Surgery, International University of Catalonia, Barcelona, Spain

⁸Department of Oral and Maxillofacial Surgery and Department of Implant Dentistry, University Medical Center Groningen, Groningen, The Netherlands

⁹ETEP (Etiology and Therapy of Periodontal Diseases) Research Group, University Complutense, Madrid, Spain

¹⁰Department of Reconstructive Dentistry, University of Iceland, Reykjavik, Iceland

¹¹Department of Oral and Maxillofacial Surgery, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands

¹²Oral Health Sciences, Kristianstad University, Kristianstad, Sweden

¹³Department of Periodontology, Eastman Dental Institute, UCL, London, UK

¹⁴Division of Maxillofacial Surgery, University of Torino, Torino, Italy

¹⁵Department of Periodontology, University of Milan, Milan, Italy

¹⁶Research Centre for the Study of Periodontal and Peri-implant Diseases University of Ferrara, Ferrara, Italy

¹⁷Graduate Implant Dentistry, Loma Linda University, Loma Linda, California

Correspondence

Søren Jepsen, Department of Periodontology, Operative and Preventive Dentistry, University of Bonn, Welschnonnenstrasse 17, 53111 Bonn, Germany.
 Email: jepsen@uni-bonn.de

Funding information

Funds for this workshop were provided by the European Federation of Periodontology in part through an unrestricted educational grant from Geistlich Pharma AG.

Abstract

Background and Aims: Bone augmentation procedures to enable dental implant placement are frequently performed. The remit of this working group was to evaluate the current evidence on the efficacy of regenerative measures for the reconstruction of alveolar ridge defects.

Material and Methods: The discussions were based on four systematic reviews focusing on lateral bone augmentation with implant placement at a later stage, vertical

bone augmentation, reconstructive treatment of peri-implantitis associated defects, and long-term results of lateral window sinus augmentation procedures.

Results: A substantial body of evidence supports lateral bone augmentation prior to implant placement as a predictable procedure in order to gain sufficient ridge width for implant placement. Also, vertical ridge augmentation procedures were in many studies shown to be effective in treating deficient alveolar ridges to allow for dental implant placement. However, for both procedures the rate of associated complications was high. The adjunctive benefit of reconstructive measures for the treatment of peri-implantitis-related bone defects has only been assessed in a few RCTs. Meta-analyses demonstrated a benefit with regard to radiographic bone gain but not for clinical outcomes. Lateral window sinus floor augmentation was shown to be a reliable procedure in the long term for the partially and fully edentulous maxilla.

Conclusions: The evaluated bone augmentation procedures were proven to be effective for the reconstruction of alveolar ridge defects. However, some procedures are demanding and bear a higher risk for post-operative complications.

KEYWORDS

barrier membrane, biomaterials, bone augmentation, bone regeneration, bone replacement graft, complications/adverse events, consensus statement, dental implants, elevation, guided bone regeneration, peri-implantitis, ridge augmentation, sinus floor

A common problem in implant dentistry is the lack of sufficient bone volume to allow for implant placement. The evidence for bone augmentation procedures was last visited by a European Workshop on Periodontology in 2008 (Tonetti & Hämmerle, 2008). The scope of this working group was to update and critically evaluate the available evidence on the efficacy of regenerative measures for the reconstruction of alveolar ridge defects and an insufficient subantral bone volume.

The group discussions and consensus were based on four systematic reviews focusing on lateral bone augmentation staged with implant placement (Naenni, Lim, Papageorgiou, & Hämmerle, 2019), vertical bone augmentation (Urban, Montero, Monje, & Sanz-Sanchez, 2019), reconstructive treatment of peri-implantitis associated defects (Tomasi, Regidor, Ortiz-Vigon, & Derks, 2019), and lateral window sinus grafting procedures (Raghoobar, Onclin, Boven, Vissink, & Meijer, 2019).

While procedures to augment bone in conjunction with implant therapy are commonly performed in a non-inflamed environment, it has to be realized that the reconstruction of peri-implantitis-related defects is challenged by the inflammatory conditions occurring in the adjacent tissues (Schwarz, Derks, Monje, & Wang, 2018). Hence, the efficacy of the latter approach primarily depends on a successful

Clinical Relevance

Scientific rationale: Reconstructive procedures for alveolar ridge defects are widely performed. It was the aim of the workshop to update the evidence for their efficacy.

Principal findings and practical implications: Clinicians should be aware that lateral and vertical ridge augmentation procedures were shown to be effective, however, are highly demanding therapies, requiring surgical training, experience, and skills. Therefore, in the treatment planning process, alternative therapeutic options with lower morbidity should always be considered. Clinicians should also be aware that the evidence regarding adjunctive reconstructive therapy at peri-implantitis-related bone defects is still limited. The long-term outcomes of maxillary lateral window sinus floor augmentation are promising; however, studies were mostly performed at specialized clinics. It is unclear whether similar results can be achieved in general practice.

resolution of peri-implant inflammation (Schwarz, Schmucker, & Becker, 2015).

1 | LATERAL BONE AUGMENTATION PRIOR TO IMPLANT PLACEMENT

The focused question of this systematic review was to assess whether primary lateral bone augmentation prior to implant placement leads to sufficient bone width in patients presenting with insufficient alveolar ridge width for implant placement (Naenni et al., 2019).

The systematic review was based on a total of 25 comparative clinical trials (16 randomized/9 non-randomized studies), which included a total of 553 patients (42.2% male; mean age of 43.9 years).

1.1 | What are the main aims, when performing lateral bone augmentation prior to implant placement?

To be able to place implants in a prosthetically ideal position for function and aesthetics without the need for additional bone augmentation.

1.2 | How were success and efficacy reported in the evaluated studies?

Most of the studies used linear measurements to assess gain in bone width either clinically (14 studies), or radiographically (six studies), or using a combination of both (three studies) at the time of implant placement (3–8 months following bone augmentation). The possibility to place implants at the augmented sites was reported in all but one of the studies.

1.3 | What were the reported outcomes following lateral ridge augmentation in the evaluated studies?

- *The feasibility of implant placement:* Although most of the studies (24 out of 25 included) reported that lateral bone augmentation allowed for subsequent implant placement, only six studies reported on the number of implants placed according to the initial planning in a prosthetically ideal position. Two studies reported on the need for a narrower implant diameter and five studies reported on the proportion of implants which needed additional bone augmentation procedures.
- *The bone width gain* as assessed radiographically and/or clinically: Clinical measurements of lateral bone gain were reported in 14 studies, whereas radiographic measurements were performed in six studies. Both clinical and radiographic assessments were reported in three studies, whereas two studies did not report on either measurement. Based on 20 studies (14 RCTs and 6 CCTs), the augmentation procedures resulted in an overall weighted mean bone width gain of 3.45 mm (*SD* 1.18) as assessed clinically, and 2.90 mm (*SD* 0.83) as measured radiographically.
- *The bone width gain* was not influenced by patient age, gender, jaw (mandible/maxilla), region (anterior/posterior areas), healing

time, or graft harvesting site. Bone width gain was negatively associated with bone width at baseline. Due to differences in treatment protocols among studies and study arms in the pooled data, the relevance of patient- and site-specific factors affecting bone width gain should be interpreted with caution.

- Based on 13 studies (seven RCTs and six CCTs), the weighted *mean bone width* following lateral bone augmentation measured 6.36 mm (95% CI: 5.73–6.99 mm).
- Based on 10 studies (eight RCTs and two CCTs), a mean weighted *loss in bone width* of –1.33 mm (95% CI: –1.78 to –0.88 mm) occurred between bone augmentation and re-entry.
- Only two studies presented *patient-reported outcome measures*. The topics addressed overall satisfaction with the procedure, the appearance of the crown, and the mucosa as well as discomfort, swelling, pain, and the amount of pain medication taken.

1.4 | Which is the most effective treatment protocol?

A complete list of the treatment protocols included in the systematic review is summarized in Table 1a (Naenni et al., 2019). Regarding graft materials, most studies investigated autologous bone (17 studies), followed by xenografts (10), allografts (6), alloplasts (2), or combinations of these (15). Grafts were used as blocks (16), particles (18), or combinations of these (9). Most treatment protocols investigated were GBR procedures using resorbable (13) or non-resorbable (5) membranes. Due to the great variability of treatment protocols and graft materials applied, a meta-analysis to assess the superiority of a specific treatment protocol could not be performed.

1.5 | What is the reported incidence of complications after lateral ridge augmentation?

Complications were reported in 17 studies. Four studies reported no complications, whereas in one study the reporting was unclear, and three studies did not provide any information on the incidence of complications. The most frequently reported complications were wound dehiscences, membrane exposure, and graft exposure (nine studies; 5%–54%). Less frequent complications included infections and loss of graft material (four studies; 7%–13%), paraesthesia (four studies; 9%–66%), and major swellings (one study; 4%).

1.6 | Implications for clinical practice

1.6.1 | What is the indication to perform lateral bone augmentation prior to implant placement?

- Lateral ridge augmentation is recommended in situations where an insufficient ridge width prevents the placement of implants in a prosthetically desirable position.

1.6.2 | How is the success of lateral ridge augmentation assessed in clinical practice?

- The procedure is successful when following healing implants can successfully be placed in the prosthetically desired position that is identified by the initial treatment plan. Clinical and radiographic measurements can be applied to assess the ridge width before and after augmentation.

1.6.3 | Which is the most effective treatment protocol?

- The systematic review failed to identify one protocol, procedure, or material to be superior for laterally augmenting the ridge prior to implant placement. Therefore, the clinician may choose among a variety of treatment protocols, procedures, and materials that have been evaluated. The materials applied encompass autologous bone, allogeneic bone, xenogeneic bone, and alloplastic bone substitute materials. Most of these materials have been applied as blocks or in particulate form. Moreover, autogenous and allogeneic bones have been combined with bone substitute materials. Most treatment protocols were GBR procedures using resorbable or non-resorbable membranes. Autologous bone grafts were predominantly harvested from intra-oral sources such as the mandibular ramus, the chin region, the maxillary tuberosity, and the nasal spine. In some studies, extraoral sources were used, including the iliac crest and the external plate of the calvarium.
- It is important to note that even in situations with narrow ridges, a substantial gain in bone width can be obtained.

1.6.4 | What is the reported incidence of complications after lateral ridge augmentation?

- Generally speaking, the reported incidence of complications associated with lateral bone augmentation was high. The most frequently reported complications were wound dehiscence, membrane exposure, and graft exposure. Depending on the clinical protocol, they occurred with an incidence ranging from 5% to 54%. Less frequent but more serious complications included infection and loss of graft with an incidence ranging from 7% to 13%. Transient paraesthesia occurred in only a few studies and showed a wide range of occurrence from 9% to 66%. The highest incidence (66%) was reported in a study harvesting bone from the chin area.
- It is expected that careful execution of an elaborate clinical technique may be key in reducing the number and the severity of the occurring complications.
- When considering the incidence and the severity of complications associated with lateral bone augmentation, it needs to be realized that this procedure may impose a burden on the patient undergoing this therapy. As a consequence, treatment options associated with lower morbidity need to be carefully evaluated during the phase of treatment planning.

1.7 | Recommendations for future research

The current systematic review failed to identify a technique representing the standard-of-care. Hence, future research should aim at finding the most efficient methods to treat lateral bone defects in different clinical situations.

1.7.1 | Assessment of the success of lateral bone augmentation prior to implant placement

- The aim of lateral bone augmentation is to enable implant placement in the desired prosthetic position. An initial treatment plan needs to be generated including the position of the planned reconstruction, the planned implant position, and consequently the planned profile of the bone. This plan determines the amount of bone to be augmented and can be used as the baseline data. Following healing, the bone profile can again be assessed radiographically or clinically. This information will determine whether the planned implant can effectively be placed in the planned position and whether the planned prosthetic reconstruction can be incorporated. In cases, where the implant can be placed but in non-optimal position or when additional procedures are required, these deviations should be meticulously reported. They may include a small or large deviation of the implant position, a narrower implant diameter than planned, a number of implants different from that planned, the need and the extent of an additional bone regeneration procedure or a change in prosthetic protocol. These considerations also apply to all staged procedures (vertical ridge augmentation, maxillary sinus floor augmentation [MFSA]).
- Measurements of bone dimensions and changes should be performed prior to the augmentation, before closing the flap and following healing. Measurements can be made clinically, radiographically, or using other imaging techniques. In addition, a form of standardization needs to be used in order to increase reproducibility.
- The incidence and nature of complications need to be carefully and completely recorded and reported for both the augmentation site and the site of autologous bone harvesting, if any.
- Given the fact that some protocols for lateral bone augmentation are associated with high patient morbidity patient-reported outcome measures should be assessed in all studies.

2 | VERTICAL RIDGE AUGMENTATION

This systematic review addressed the focused question of what is the effectiveness of vertical bone augmentation procedures on clinical vertical alveolar ridge gain (Urban et al., 2019).

It was based on 34 studies, of which six were randomized clinical trials, RCTs (five with a parallel and one with a split-mouth design), four controlled clinical trials, CCTs, 16 prospective case series, CS, and eight retrospective case series.

The resulting systematic review pooled data from 678 patients at baseline, with a total of 1,392 implants. At the end of the follow-up period, among the studies included in this systematic review, 668 patients and a total of 1,309 implants were analysed.

2.1 | What are the main aims when performing a vertical bone augmentation?

The main aims when performing a vertical bone augmentation procedure are (a) to achieve the necessary bone volume to allow the placement of dental implants in a prosthetically driven position and (b) to improve aesthetics. However, none of the included studies clearly reported on these aims.

2.2 | In what clinical conditions has vertical ridge augmentation been investigated in the included studies?

Vertical ridge augmentation was investigated in partially (34 studies) as well as fully edentulous (two studies) patients. Amongst partially edentulous patients, single as well as multiple tooth span defects were treated in all areas of the jaw. Additionally, eight studies evaluated the outcome of vertical ridge augmentation procedures in the posterior mandible and six studies in the anterior maxilla.

2.3 | What was the efficacy of vertical ridge augmentation assessed in the systematic review?

The systematic review regarded vertical bone gain as the primary outcome, which was reported in all studies. Nineteen studies (3 RCTs, 2 CCTs, 14 CS), which reported a *staged* vertical ridge augmentation protocol, used heterogeneous methods to measure the vertical defect height and/or bone gain, with a range between 2 and 9.9 mm.

Eleven studies (three RCTs, one CCT, seven CS), which reported on a *simultaneous* vertical ridge augmentation protocol, measured the vertical defect height from the base of the defect to the implant shoulder by linear measurements using a periodontal probe, with a range for vertical bone gain between 1 and 5.85 mm.

The weighted mean clinical vertical bone gain for all the studies (33 studies: 6 RCTs, 4 CCTs, 23 CS) was 4.16 mm (95% CI: 3.72–4.61 mm). The clinical vertical bone gain varied among the different procedures, with a weighted mean gain of 8.04 mm for distraction osteogenesis (three studies), 4.18 mm for guided bone regeneration (20 studies), and 3.46 mm for bone blocks (12 studies).

2.4 | What was the complication rate after vertical ridge augmentation using different approaches?

Based on 28 studies (29 arms), the systematic review reported a weighted mean complication rate of 16.9% (95% CI: 12.5–21). For the *staged* approach, the range of complications varied from 0% to

77.8% (15 studies; 3 RCTs, 1 CCT, 11 CS), whereas for the *simultaneous* approach, it varied from 0% to 45.4% (10 Studies; three RCTs, one CCT, six CS). The complication rate was also influenced by the type of procedure with a 47.3% complication rate for distraction osteogenesis (three CS), 12.1% for guided bone regeneration (6 RCTs, 3 CCTs, 11 CS) and 23.9% for the use of blocks (two RCTs, two CCTs, five CS).

Most studies reported on graft/membrane exposure, post-operative infection, and loss of graft material, although few studies differentiated between major and minor complications.

2.5 | What is the current evidence for implant survival and success rates after vertical ridge augmentation?

Implant survival was reported in most of the studies (27 studies). The aggregated mean implant survival rate was 98.95% (range 90.5%–100%). However, the implants were followed for at least 5 years in only four studies.

On the contrary, implant success using specific criteria was rarely reported (six studies), with a success range between 85% and 100%.

2.6 | What is the current evidence on the stability of the peri-implant tissues following vertical ridge augmentation?

When looking at the stability of peri-implant tissues following vertical ridge augmentation, different parameters were monitored. Eleven studies reported on marginal bone levels for at least 12 months after loading, with a weighted mean bone loss of 1.01 mm. The amount of bone loss was different depending on the type of procedure.

Distraction osteogenesis showed a bone loss of 1.4 mm, guided bone regeneration of 0.99 mm, and autologous bone blocks of 0.77 mm. Additionally, only four studies reported on probing depth (PD) and three studies on gingival or bleeding indices.

When dealing with the incidence of biological complications around implants, only two articles adhered to specific case definitions for peri-implantitis, reporting cumulative incidences of 0% and 3.73%.

2.7 | Implications for clinical practice

- Vertical ridge augmentation is a highly technique sensitive surgical intervention to be performed by highly experienced clinicians. The key elements are
 - Appropriate graft/barrier stabilization
 - Appropriate flap management and soft tissue closure
- Alternative treatment options should always be considered prior to the application of vertical ridge augmentation. Patient's expectations, age, and individual characteristics must be carefully considered.

- The reported complication rate for vertical ridge augmentation is high and varies amongst different techniques. Frequently observed graft/membrane exposures and post-operative infections may lead to a bacterial contamination of adjacent implant surfaces. Therefore, it may be safer to perform vertical ridge augmentation as a staged procedure.
- Due to the high rate of complications (i.e. loss or incorrect inclination of the segment, frequent need for additional lateral ridge augmentation), distraction osteogenesis is seldom recommended.
- Appropriate temporization is crucial to decrease complications. No pressure should be applied to the surgical area by the temporary restoration. When treating totally edentulous patient, caution is advised as removable temporary restorations may jeopardize the outcome of vertical ridge augmentation.

2.8 | Recommendations for future research

- Future research should (a) Identify the most appropriate and efficacious technique according to specific requirements, (b) Identify a standard, non-invasive measurement technique for baseline and follow-up assessments of defect/jaw dimensions, (c) Consider feasibility of prosthetically driven implant placement after vertical ridge augmentation as an outcome.
- Since most studies were case series and a few were controlled studies, future research should focus on conducting multicentre, randomized and controlled trials. However for this specific intervention, ethical considerations may prevent the inclusion of a negative control (no augmentation). Randomized and controlled trials should be carried out comparing different approaches for treatment (i.e. short implants etc.) and/or different techniques for vertical ridge augmentation.
- Future research should report results on interventions performed in the different specific regions.
- Outcome measures focused on marginal bone stability, peri-implant tissues, and PROMs are scarcely reported, hence future research should assess these parameters. Reports should focus on short- and long-term outcomes.
- Research should investigate the correlation between width and height in vertical ridge augmentation for the long-term maintenance of the vertically augmented bone.
- Research should establish optimal graft placement and implant healing times for different vertical ridge augmentation techniques.

3 | RECONSTRUCTION OF PERI-IMPLANTITIS-RELATED BONE DEFECTS

This systematic review addressed the focused question of what is the benefit of using a reconstructive technique as adjunct to surgical therapy of peri-implantitis (Tomasi et al. 2019).

Peri-implantitis is a pathological condition occurring in tissues around dental implants. It is characterized by inflammation in the

peri-implant connective tissue and progressive loss of supporting bone (Berglundh et al., 2018; Schwarz et al., 2018).

The primary goal of treatment of peri-implantitis has been established as resolution of the inflammation and prevention of further bone loss (Sanz & Chapple, 2012).

Peri-implantitis may result in the formation of an intrabony defect associated with the implant. Where intrabony defects are present, there is potential to regenerate or reconstruct the bone defect. Hence, in addition to resolution of peri-implant inflammation, the goals of reconstructive surgery are

- to regenerate the bony defect
- to achieve re-osseointegration
- to limit peri-implant soft tissue recession.

It is realized, however, that histology is the only way to demonstrate bone regeneration and re-osseointegration. Therefore, ideally, evidence from clinical studies should be supplemented with data from exemplary human histology.

This systematic review addressed the focused question of the benefit of using a reconstructive technique as an adjunct to surgical therapy of peri-implantitis.

The potential benefit of reconstructive techniques over control procedures (open flap debridement [OFD]—access flap surgery) was evaluated in three randomized controlled trials, representing a total of 116 patients with 116 implants.

3.1 | What were the inclusion criteria in the selected studies for using reconstructive measures as an adjunct in the surgical therapy of peri-implantitis?

Inclusion criteria were

- an intrabony compartment of the peri-implantitis-related defect of >2 mm (two studies), ≥ 3 mm (four studies), and >3 mm (three studies)
- PD ≥ 5 mm (three studies), >5 mm (three studies), ≥ 6 mm (two studies), and >6 mm (three studies)
- presence of keratinized mucosa (six studies)
- crater-like defect morphology (four studies), 3–4 wall defect (one study), and 2–3 wall defect (one study) in patients:
- not smoking >10 cig/day (four studies) and >20 cig/day (one study)
- without uncontrolled diabetes (10 studies)

3.2 | How were the outcomes of reconstructive procedures assessed?

In addition to indicators of peri-implant health (bleeding scores/suppuration on probing), the following parameters were assessed:

- bone fill and alterations of marginal bone levels on radiographs

- changes in PDs
- changes of clinical attachment levels
- peri-implant soft tissue recession

3.3 | What were the criteria used for clinical success following reconstructive procedures?

Three of the 16 studies (two RCTs, one case series) included in the systematic review defined clinical/radiographic endpoints (composite outcomes) to describe clinical success. The composite outcomes included

- Absence of additional bone loss
- PD <5 mm (three studies) or ≤6 mm (one study). One study applied two different composite outcomes
- Absence of bleeding/suppuration (at four sites/implant in eight studies, at six sites/implant in seven studies, not reported in one study)

One additional RCT (Renvert, Roos-Jansaker, & Persson, 2018), published after the search in the systematic review was completed, also used a composite outcome including radiographic defect fill ≥1.0 mm as one of the parameters.

3.4 | What are the reported benefits of the adjunctive use of a reconstructive technique?

Based on three studies (three RCTs, 116 patients/implants), a statistically significant benefit in terms of marginal bone level gain (WMD = 1.7 mm; 95% CI: 0.3–3.1 mm; $p = 0.02$) was observed in favour of the reconstructive interventions (porous Ti-granules, enamel matrix derivative—EMD) versus control (OFD). Defect fill was reported in two studies (porous Ti-granules) with controls (two RCTs, 91 patients/implants), indicating a statistically significant greater fill at test sites (WMD = 56.5%; 95% CI: 39.3–73.8; $p < 0.001$).

One study evaluating the use of EMD (RCT, 25 patients/implants) also included in the overall meta-analysis failed to demonstrate any additional benefit for marginal bone level gain (0.5 mm; 95% CI: –0.4 to 1.3 mm).

No differences for any of the clinical measures (PD reduction, BOP reduction) or composite outcomes were demonstrated. Changes of clinical attachment and soft tissue levels were not assessed. None of the included studies addressed patient-reported outcome measures.

One additional RCT (Renvert et al., 2018) (41 patients, 41 implants), published after the search in the systematic review was completed, tested the use of a xenograft compared to OFD alone. In contrast to the findings of the meta-analysis, no differences in terms of marginal bone level changes were observed between treatment groups. There were also no differences in reduction of soft tissue inflammation and soft tissue recession.

The study, however, indicated greater reductions of PDs in the test group.

3.5 | What were the results from comparative studies assessing different graft materials?

One RCT (45 patients, 75 implants) compared two different grafting materials (xenogeneic material vs. autologous bone) and indicated greater marginal bone level gain and PD reduction for the xenogeneic material.

One additional RCT (20 patients, 20 implants) evaluated two different reconstructive procedures (hydroxyapatite vs. xenogeneic material combined with a membrane) and described greater BOP and PD reductions as well as CAL gains for the combined technique (xenogeneic material combined with a membrane).

3.6 | What were the reported factors affecting outcomes of reconstructive procedures?

Two observational studies (27 patients/implants and 71 patients/implants) analysed the effect of the defect configuration on outcomes. One of them, employing a stabilized collagenous bovine bone mineral failed to identify an impact on disease resolution. The other, using bovine bone particles along with a collagen membrane, associated greater attachment gain with circumferential defects.

One observational study (26 patients/implants) evaluated implant surface characteristics as a predictor of treatment outcome and found significantly better results at implants with a moderately rough surface when compared to rough-surfaced implants.

None of the available studies addressed potential patient-related factors.

3.7 | What were the complications associated with reconstructive procedures?

Fifteen out of the 16 studies reported on adverse events occurring after the surgical intervention. Among the 12 studies (two RCTs, 10 observational studies) with a transmucosal healing protocol, seven reported an uneventful healing. Two studies using a membrane reported an exposure at 18% and 44% of implant sites, while three studies applying bone replacement grafts described the occurrence of flap dehiscence and post-surgical infection. In one RCT applying a submerged healing protocol, flap perforation at 3 weeks was observed at 47% of implant sites. In two observational studies combining the submerged healing protocol with the use of a barrier membrane, complications occurred at 31% and 59% of the implant sites, respectively.

3.8 | What was the long-term survival (≥5 years) of implants treated with reconstructive therapy?

Two studies (one RCT based on 17 out of originally 32 patients, one case series based on 24 out of originally 26 patients) reported an

implant loss of 17%–18%, while one study (case series based on 25 out of originally 38 patients) observed no implant loss in the long term.

3.9 | Implications for clinical practice

3.9.1 | Which patient-related factors should clinicians consider when recommending reconstructive procedures as an adjunct in the surgical therapy of peri-implantitis?

Before considering reconstructive procedures as part of the treatment of peri-implantitis, the clinician should aim to meet the following patient-related conditions:

- Patients willingness to undergo the intervention and participate in a supportive care programme
- Realistic patient expectations
- Low full-mouth plaque scores (<20%)
- Low full-mouth bleeding scores (<20%)
- Smoking <10 cigarettes/day
- No medical contraindications for surgical/reconstructive intervention

3.9.2 | Which site-related factors should clinicians consider when recommending reconstructive procedures as an adjunct in the surgical therapy of peri-implantitis?

Before considering reconstructive procedures as part of the treatment of peri-implantitis, the clinician should assess the following site-related factors:

- The depth of the intrabony defect which should be a minimum of 3 mm
- The defect configuration which should ideally be an isolated 3 or 4 wall contained defect
- Presence of keratinized mucosa

3.9.3 | Which treatment protocols (e.g. materials/ techniques) can be recommended?

A protocol should include

- Flap design that allows adequate access to the defect and adequate coverage and stability of the graft material.
- Removal of inflamed tissue
- Decontamination of the implant surface
- Placement of the graft material (with or without a barrier membrane)
- Adequate flap adaptation
- Adequate post-operative care (including a post-operative period of use of chlorhexidine digluconate solution).

3.9.4 | How should clinicians assess outcomes of reconstructive procedures?

The reconstructive outcome should be evaluated following a healing period of at least 6 months and include

- Change in PD.
- Presence or absence of BOP/suppuration.
- Defect fill evaluated on radiographs/radiographic defect fill
- Change in peri-implant soft tissue level
- Patient satisfaction following treatment.

3.10 | Recommendations for future research

3.10.1 | Which are the critical questions that should be addressed in future clinical studies?

The influence of the following factors on treatment outcome should be addressed:

- The adjunctive benefit of the reconstructive method (compared to OFD)
- Implant surface characteristics
- Implant geometry
- Reconstructive techniques and materials (augmentation materials, barrier membranes, and biologic agents)
- Bone defect configuration and characteristics
- Presence of keratinized mucosa
- Smoking
- Systemic health
- Mode of healing (submerged vs. non-submerged)
- Peri-operative systemic antimicrobials

3.10.2 | What outcomes should be assessed in future clinical studies?

- Implant survival
- Imaging technologies to assess defect fill
- Change in PD
- Change in BOP
- Change in of suppuration
- Change in peri-implant soft tissue levels
- Patient-reported outcomes.
- Composite outcomes: including the following parameters: bone fill, peri-implant soft tissue recession, PD, bleeding on probing, suppuration.

Example of a composite outcome used in evaluation of a reconstructive technique (Renvert et al., 2018):

≥1 mm radiographic defect fill + PD ≤5 mm + peri-implant soft tissue recession <1 mm, no suppuration and no bleeding.

4 | SINUS FLOOR AUGMENTATION—LONG-TERM RESULTS

This systematic review addressed the focused question of the long-term (>5 years) effectiveness of MFSA procedures using the lateral window technique. It is based on 11 prospective cohort studies with a total of 383 patients, 615 MFSA procedures, and 1,517 implants (Raghoebar et al., 2019).

4.1 | What was the clinical indication for maxillary sinus floor elevation in the systematic review?

The clinical indication for MFSA was reduced residual subantral bone height (≤ 6 mm) due to alveolar ridge resorption and maxillary sinus pneumatization which did not allow for placement of standard size implants. The interarch relationship was not reported in any of the included studies.

4.2 | How was the bone gain assessed in the included studies?

The bone gain was assessed on two-dimensional radiographs (11 studies) taken immediately after surgery (baseline) and after healing periods ranging from 6 weeks to 18 months.

4.3 | What was the long-term (≥ 5 years) survival rate of implants placed in conjunction with maxillary sinus floor elevation using the lateral window technique?

Based on 11 prospective studies, reporting on 383 patients receiving 615 maxillary sinus floor elevation procedures and 1,517 implants, the estimated annual implant loss was 0.43% (95% CI: 0.37–0.49) representing a 5-year implant survival rate of 97.8%.

4.4 | What were the reported outcomes in the evaluated studies?

The reported outcomes were implant loss (11 studies), mean marginal bone loss (nine studies), and surgical complications (10 studies).

4.5 | What were the factors that influenced the outcomes of maxillary sinus floor elevation using the lateral window technique?

Based on the meta-analyses of this systematic review, the incidence of implant loss was similar in partially (five studies) and fully edentulous patients (three studies), delayed (two stage) (eight studies) or simultaneous (one stage) (four studies) implant placement, and for different grafting materials (autologous bone [three studies], deproteinized bovine bone mineral [three studies], synthetic bicalcium phosphate [one study]).

4.6 | What was the reported complication rate associated with maxillary sinus floor elevation using the lateral window technique?

Complications reported in the systematic review were perforations of the Schneiderian membrane (18%), post-operative bleeding (14.5%), infections (1%), pain (0.6%), abscess (0.2%), and sinusitis (0.2%).

4.7 | Implications for clinical practice

- The insertion of dental implants in combination with MFSA is an effective treatment method showing high long-term implant survival rates. This finding applies for both the partially and fully edentulous maxilla.
- Both particulate autologous bone and bone substitutes can be used as grafting materials. Harvesting of autologous bone may be associated with increased patient morbidity.
- If primary stability of the implants can be achieved, a simultaneous procedure (one stage) can be recommended.

4.8 | Recommendations for future research

- In order to evaluate the outcome of MFSA and survival of implants inserted in combination with MFSA prospective long-term cohort studies (≥ 10 years) reporting on implant-based and patient-based data are needed. Those studies should include information on residual subantral bone height, risk factors, surgical techniques, materials used, post-surgical protocols, complications, implant survival, marginal bone levels, and graft stability evaluated in a three-dimensional direction.
- Comparative randomized studies on different surgical techniques and materials are needed.

ACKNOWLEDGEMENTS

The authors acknowledge the contribution of the representative from the sponsor (Geistlich Pharma AG), Jürg Zumbunn, for his contribution during the workshop.

CONFLICT OF INTEREST

Workshop participants filed detailed disclosure of potential conflict of interest relevant to the workshop topics and these are kept on file. Declared potential dual commitments included having received research funding, consultant fees and speakers fees from: Botiss, Camlog, CLC Implants, Colgate, Curanden, DentaId, Dentium, Dentsply Implants, Eklund Foundation, Geistlich Pharma AG, ITI Foundation, Henry Schein, Mectron, NeoOss, Nobel Biocare, Orthocell, Osteogenics Biomedical, Osteology Foundation, Osteoready, Procter & Gamble, Regedent, Straumann, Sunstar, Thommen Medical.

ORCID

- Søren Jepsen  <https://orcid.org/0000-0002-4160-5837>
- Frank Schwarz  <https://orcid.org/0000-0001-5515-227X>
- Jan Derks  <https://orcid.org/0000-0002-1133-6074>
- Nadja Naenni  <https://orcid.org/0000-0002-6689-2684>
- Gerry M. Raghoebar  <https://orcid.org/0000-0003-3578-7141>
- Stefan Renvert  <https://orcid.org/0000-0003-0992-2362>
- Ignacio Sanz-Sánchez  <https://orcid.org/0000-0002-3698-4772>
- Cristiano Tomasi  <https://orcid.org/0000-0002-3610-6574>

REFERENCES

- Berglundh, T., Armitage, G., Araujo, M. G., Avila-Ortiz, G., Blanco, J., Camargo, P. M., ... Zitzmann, N. (2018). Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the classification of periodontal and peri-implant diseases and conditions. *Journal of Clinical Periodontology*, 45(Suppl 20): S286–S291.
- Naenni, N., Lim, H. C., Papageorgiou, S., & Hämmerle, C. H. F. (2019). Efficacy of lateral bone augmentation prior to implant placement: A systematic review and meta-analysis. *Journal of Clinical Periodontology*, 46(Suppl 21), 287–306.
- Raghoebar, G., Onclin, P., Boven, G., Vissink, A., & Meijer, H. J. A. (2019). Long-term effectiveness of maxillary sinus floor augmentation. A systematic review and meta-analysis. *Journal of Clinical Periodontology*, 46(Suppl 21), 307–318.
- Renvert, S., Roos-Jansaker, A. M., & Persson, G. R. (2018). Surgical treatment of peri-implantitis lesions with or without the use of a bone substitute – a randomized clinical trial. *Journal of Clinical Periodontology*, 45, 1266–1274.
- Sanz, M., Chapple, I. L. C. & on behalf of Working Group 4 of the VIII European Workshop on Periodontology (2012). Clinical research on peri-implant diseases: Consensus report of Working Group 4. *Journal of Clinical Periodontology*, 39(Suppl. 12), 202–206.
- Schwarz, F., Derks, J., Monje, A., & Wang, H. L. (2018). Peri-implantitis. *Journal of Clinical Periodontology*, 45(Suppl. 20), 246–266.
- Schwarz, F., Schmucker, A., & Becker, J. (2015). Efficacy of alternative or adjunctive measures to conventional treatment of peri-implant mucositis and periimplantitis: A systematic review and meta-analysis. *International Journal of Implant Dentistry*, 1, 22.
- Tomasi, C., Regidor, E., Ortiz-Vigon, A., & Derks, J. (2019). Efficacy of reconstructive surgical therapy at peri-implantitis-related bone defects. A systematic review and meta-analysis. *Journal of Clinical Periodontology*, 46(Suppl 21), 340–356.
- Tonetti, M. S., & Hämmerle, C. H. F. (2008). Advances in bone augmentation to enable dental implant placement: Consensus Report of the Sixth European Workshop on Periodontology. *Journal of Clinical Periodontology*, 35(Suppl. 8), 168–172.
- Urban, I. A., Montero, E., Monje, A., & Sanz-Sanchez, I. (2019). Effectiveness of vertical ridge augmentation interventions. A systematic review and meta-analysis. *Journal of Clinical Periodontology*, 46(Suppl 21), 319–339.

How to cite this article: Jepsen S, Schwarz F, Cordaro L, et al. Regeneration of alveolar ridge defects. Consensus report of group 4 of the 15th European Workshop on Periodontology on Bone Regeneration. *J Clin Periodontol*. 2019;46(Suppl. 21):277–286. <https://doi.org/10.1111/jcpe.13121>

