# How effective are different ridge augmentation strategies at resolving horizontal alveolar ridge deficiencies prior to (staged approach), or simultaneous with dental implant placement?

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**A critical appraisal of a systematic review:** I. Sanz-Sánchez, A Ortiz-Vigón, I. Sanz-Martin, E. Figuero, M. Sanz. Effectiveness of lateral bone augmentation on the alveolar crest dimension: A Systematic review and meta-analysis.

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## Summary

**Systematic review conclusion:** Lateral ridge augmentation procedures are effective in treating deficient alveolar ridges prior or simultaneously to the placement of dental implants. For the simultaneous approach, the combination of bone replacement grafts and barrier membranes was associated with superior outcomes. For the staged approach, the combination of bone blocks, particulate grafts, and barrier membranes provided the best outcomes. The morbidity and postoperative complications associated with the staged approach should not be underestimated. Both treatment strategies led to high survival and success rates (>95%) for the implants placed on the regenerated sites.

## Critical appraisal conclusion

Different ridge augmentation strategies resulted in statistically significant defect height and width reductions in the simultaneous approach and achieved significant bone width gains in the staged approach. Follow-up was too short (median = 6 months) to establish the long-term efficacy. The results suggest that for the simultaneous approach, the combination of bone replacement grafts with barrier membranes presented with better outcomes. For the staged approach, bone blocks combined with particulate graft material and bio absorbable membranes showed better bone width gains. However, increased morbidity and postoperative complications was observed with the latter intervention. The most frequent adverse events reported for both the simultaneous and staged approach were membrane and/or graft exposure. Non-exposed grafts presented with better bone width gains compared to exposed grafts. Overall, the lack of good quality randomized controlled trials, variability in research methodology amongst individual studies, and risk of bias factors resulted in poor quality of evidence therefore potentially reducing the validity of the results. Therefore, any clinical decisions regarding superiority or inferiority of ridge augmentation strategies or biomaterials should be interpreted with caution.

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## Implications for clinical practice:

Knowledge and understanding of grafting materials and surgical techniques play a critical role in the predictable and successful management of simple and complex alveolar defects to facilitate dental implant therapy. Ridge augmentation procedures should always follow a prosthetically driven treatment plan to allow placement of the implant in the correct 3D position. The anatomy of the defect has to be assessed not only in relation to the type of resorption (horizontal, vertical or combined), or to the size of the defect (volume of lost bone), but also in relation to the neighboring teeth. Use of CBCT scanners for assessment of the bone volume and pretreatment planning allows clinicians to anticipate more confidently whether a simultaneous or staged approach should be taken. Primary wound closure is fundamental for the successful outcome of alveolar ridge augmentation. The primary objectives include containing graft materials, optimizing blood supply to the surgical site, and preventing bacterial contamination and mechanical irritation of the augmented site. Adequate soft tissue conditions must be present and good surgical techniques should be applied to ensure successful and predictable primary soft tissue coverage of the augmented site. Clinicians should always opt for a treatment strategy that is least invasive and least risk of surgical and postoperative complications.

## Clinical question

In situations with horizontal alveolar ridge deficiencies, how effective are different regenerative surgical interventions at increasing the width of the alveolar ridge and resolving crest deficiencies?

## Review methodology

The systematic review and meta-analysis was conducted by following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines.[1] The electronic databases of the National Library of Medicine (MEDLINE Pubmed) and Cochrane Central Register of Controlled Trials were searched for human clinical trials on lateral ridge augmentation (simultaneous or staged approach) published until December 2014. Only randomized controlled clinical trials (RCTs), controlled clinical trials (CCTs), and prospective case series with a minimum sample size of 10 patients and a minimum follow-up time of 6 months were eligible. Participants had to be >18 years and in good general health requiring the placement of 1 implant in sites presenting ridge deficiencies.

The primary outcomes measured were the changes between baseline and the reentry 3 to 9 months later in the alveolar ridge width and height dimensional changes in the simultaneous approach, and the width dimension of the ridge in the staged approach. Two reviewers independently and in duplicate assessed the quality and risk of bias of the included RCTs and CCTs, following the Cochrane Collaboration recommendations[2] and the Newcastle-Ottawa scale for the cohort studies. [3]

Appropriate statistical testing and analysis was conducted to establish heterogeneity and average estimate of treatment effect. The data on the primary and secondary outcomes were pooled and described with weighted mean differences (WMDs) and 95% confidence intervals (CIs) using the random effects model.

## Main results

From the 40 selected studies, 21 investigated the simultaneous approach (2 CCTs, 9 RCTs, and 10 case series), seventeen (17), the staged approach (3 CCTs, 3 RCTs, and 11 case series), and two (2), the ridge expansion procedure (2 case series). This systematic review pooled data of 1,242 patients at baseline, with a total of 1,881 implants placed. The mean follow-up period was of 21.48 months, with a minimum of 4 months. When stratified by treatment group, 783 patients were treated with the simultaneous approach (755 completed the follow-up), 373 patients with the staged approach (364 completed the follow-up).

## Primary outcome: defect width reduction with simultaneous approach

The maximum defect width reduction was obtained for the combination of particulate xenograft + BMP + bio absorbable membrane (WMD = – 5.69 mm; 95% CI: –6.68, –4.69; $P < 0.001$). The GBR procedure combining particulate xenograft + bio absorbable membrane was the most frequently used procedure ($n = 7$), demonstrating a significant reduction in the defect width (WMD = – 3.28 mm; 95% CI: –3.72, –2.82; $P < 0.001$).

From eight RCT's or CCT's included the meta-analysis only 1 found a statistical significant difference between test and control, showing a higher reduction in alveolar bone width when using a particulate synthetic graft with a collagen bio

absorbable membrane as compared with the use of the same graft with a crosslink bio absorbable collagen membrane (WMD = 1.00 mm; 95% CI: 0.58, 1.41; P < 0.001). The intervention combining bone replacement grafts with barrier membranes was associated with superior outcomes.

### Primary outcome: bone width gain with staged approach

The greatest bone width gain was reported for the combination of particulate xenograft + autologous bone + bio absorbable membrane (WMD = 5.68 mm; 95% CI: 5.00, 6.35; P < 0.001). The lateral bone augmentation procedure using an autologous bone block alone was the most frequently used (n = 6) demonstrating a significant width gain (WMD = 4.25 mm; 95% CI: 4.04, 4.47; P < 0.001).

In RCTs and CCTs, 4 studies used autologous bone blocks as control group and were compared with different test treatments (autologous particulate + non-bio absorbable membrane; autologous block + particulate xenograft; autologous block + non-bio absorbable membrane; autologous block + particulate xenograft + bio absorbable membrane). The meta-analysis demonstrated better results, although statistically non-significant with autologous bone blocks (WMD = – 0.27 mm; 95% CI: –1.16, 0.61; P < 0.545).

### Secondary outcomes: survival and success rates and adverse effects

Both simultaneous and staged treatment strategies led to high survival and success rates (>95%) for the implants placed on the regenerated sites.

The most frequent adverse events reported for either the simultaneous or staged approach were membrane and/or graft exposure. The need of regrafting was reported in 7 studies and ranged from 0% to 23.5%. For the simultaneous approach, non-exposed membrane cases demonstrated a significant higher reduction in vertical bone (WMD = 1.01 mm; 95% CI: –0.38, 1.64; P < 0.002). The staged approach also showed a significant higher bone width gain in the non-exposed cases (WMD = 3.10 mm; 95% CI: 2.58, 3.61; P < 0.001).

### Conclusion

Lateral ridge augmentation procedures are effective in treating deficient alveolar ridges prior to or simultaneously with the placement of dental implants. For the simultaneous approach, the combination of bone replacement grafts and barrier membranes was associated with superior outcomes. For the staged approach, the combination of bone blocks, particulate grafts, and barrier membranes provided the best outcomes. The morbidity and postoperative complications associated with the staged approach should not be underestimated.

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## Commentary

### Background and importance

A basic requirement for a successful and predictable treatment outcome with dental implant therapy is the presence of adequate bone volume to support the required number and distribution of osseointegrated implants in their correct three-dimensional position.[4] When bone volume is deficient due to ridge atrophy, dento-alveolar trauma (i.e. traumatic extractions) or pathosis, implant therapy may not be possible unless the alveolar ridge is augmented sufficiently. A horizontal ridge augmentation with the staged approach enables the placement of a dental implant at a subsequent intervention. An alveolar ridge augmentation procedure with simultaneous implant placement is usually used to augment smaller bone defects or to cover exposed threads in dehiscence or fenestration type defects. Staged or simultaneous ridge augmentation procedures are well documented, well accepted and considered predictable and widely performed with different guided bone regeneration (GBR) techniques with varying outcomes around the word.[5,6]

The GBR technique refers to the use of barrier membranes (resorbable or non-resorbable) in the treatment of alveolar ridge defects.[5] Barrier membranes are placed for various reasons, namely its separating effect (to separate the bone graft from the overlying soft tissues allowing the grafted site to be populated with new blood vessels and osteogenic cells; to stabilize the blood coagulum and any particulate grafting materials underneath; and to protects the graft from sharp edges of bone blocks and other biomaterials potentially leading to dehiscences.[5] Membranes are also used for creating and maintaining space. In such cases non-resorbable membranes or resorbable collagen membranes, in combination with tenting pins or screws to support or secure the membrane, are used to prevent collapse of the membrane into the defect. The natural matrix for bone healing is the fibrin of the blood clot.[5] Any implanted material

that promotes bone healing is defined as a bone graft.[7] Ideally a grafting material must be: osteoconductive (allow or direct new bone to form within the material structure); osteoinductive (provide recruitment and /or differentiation factors for bone forming cells; and osteogenic (provide induced or inducible bone forming cells). Different bone grafting materials and techniques are available, depending on the indication and intended resorption period, to guarantee the stability and reorganisation of the augmented area. In general, augmentation materials are classified as: autologous (autogenous/ harvested from the same patient), allogenic (homologous/derived from the other humans), xenogenic (heterologous/ derived from animal species) and alloplastic bone substitute (synthetic). Ridge augmentation serves three primary objectives. Firstly, to restore function by creating volume of vital bone that will accommodate a dental implant in its ideal 3D position. Secondly, to promote aesthethics by giving the associated soft tissues the bony support needed for an aesthetic appearance and stability of the restoration. Thirdly, to ensure a predictable long-term prognosis of the implant by creating sufficient bone volume coronally around the neck of the implant, ensuring a tight soft-tissue protective seal.[5]

This meta-analysis is the first study to evaluate the relative effectiveness of different ridge augmentation strategies on the dimensional changes in the alveolar bone prior to (staged), or simultaneous with implant placement.

## Are the results valid?

The research methodology used for the meta-analysis was well conducted, therefore the results presented are considered valid within reason.

However, the validity of the meta-analysis and reliability of the evidence presented depends heavily on the validity of the individual studies and is only as reliable as the research methods used in each of the primary studies. In other words, conducting a meta-analysis does not overcome problems that were inherent in the design and execution of the primary studies. The primary studies presented with several important limitations that could affect the reliability of evidence presented.

## Heterogeneity

The individual studies are characterized by diverse study designs and variations in methodological quality (outcomes measured, standardization of measurement criteria, and follow-up times), interventions and biomaterials used, and types of alveolar bone defects studied (simple or complex, partially edentulous or edentulous, anterior or posterior, maxilla or mandibular). Anterior and posterior parts of the maxilla and mandibula have different bone qualities; hence they have different regenerative capacities.[8] Furthermore, the length of the defect may affect the degree of vascularization to the augmented site.[8] The high variability in terms of the interventions for ridge augmentation and the different combinations of bone replacement grafts and barrier membranes used resulted in reduced number of studies within each subgroup thus making it very difficult to allow for adequate statistical analysis.

## Quality and bias

The individual studies were generally of a poor quality presenting with a high risk of bias for most of the criteria. Combining studies of poor quality and overly biased data with those that were more rigorously conducted may not be useful and can lead to worse estimates of the underlying truth or a false sense of precision around the truth, thus compromising the reliability of the data.

## Study design

The influence of study design on the magnitude of the outcome of the average treatment effect may have a negative effect on the reliability of the results presented. The results from the case series studies were superior when compared to that of the RCT's. Including such studies in a meta-analysis may lead to overestimation of the average treatment effect. An important consideration and limitation is that the interventions were not tested head on in a comparative analysis thus compromising the magnitude of the effect.

## Number of studies and sample size

Inadequate number of studies in the subgroup analysis may also result in inability to examine heterogeneity reliably. This combined with small sample sizes may affect the reliability of average estimations of the treatment effect.

## Lacking important data and clinical significance

Individual studies were lacking data on important long-term outcomes such as aesthetic outcome and soft tissue and bone stability, as well as patient reported outcomes and costs.

The CI for the WMD of the pooled data as well as for subgroups does not include 0 therefor showing a statistically significant difference. However a statistically significant finding by itself can have very little to do with clinical practice and has no direct relation to clinical significance[9] Judgements about clinical significance should take into

consideration how the benefits and adverse events of an intervention are valued by the patient. These parameters were not adequately reported on in the individual studies.[9]

### Strengths

On the positive side, the meta-analysis has important strengths that may contribute towards supporting the validity of the data. The width of CI's in the reported data of individual studies was small, thus indicating precision of the average estimate of the treatment effect. Furthermore, the results of the combined data, as well as RCT plus CCT's separately, consistently showed a positive average estimate of treatment effect thus lending support to the effectiveness of the interventions.

Overall, the lack of good quality comparative trials, heterogeneity and variability in research methodology amongst individual studies, and risk of bias factors resulted in poor quality of evidence therefore potentially reducing the validity of the results. Any clinical decisions regarding superiority or inferiority of interventions or biomaterials should be interpreted with caution.

## What are the key findings?

### Effectiveness

The meta-analysis showed that different ridge augmentation strategies resulted in statistically significant defect height and width reductions (baseline vs. final) in the simultaneous approach and achieved significant bone width gains in the staged approach for the interventions and combinations of biomaterials used. The results suggest that for the simultaneous approach, the combination of bone replacement grafts with barrier membranes presented with better outcomes. For the staged approach, bone blocks combined with particulate graft material and bio absorbable membranes showed better bone width gains. However, increased morbidity and postoperative complications was observed with the latter intervention.

### Success and implant survival rates

The success rates of simultaneous and staged ridge augmentation procedures were high, ranging from 73.3% to 100%. (19 studies did not report success rates) The short-term implant survival rate likewise was also high ranging from 78,2% to 100%. (5 studies did not report on the implant survival rate). The median follow-up period was 6 months (7 studies reported no follow-up).

### Adverse events

For both the simultaneous as well as the staged approach, the most frequently reported adverse event was membrane and/or graft exposure.

Significant higher bone width gains (WMD = 3.10mm; 95% CI: 2.58, 3.61) and defect height reduction (WMD = 1.01 mm; 95% CI: -0.38, 1.64) were achieved in non-exposed compared to exposed cases. The need for regrafting was reported in 7 studies and ranged from 0% to 23,5%

## How are the results of this review applicable in clinical practice?

### Are these interventions feasible?

The simultaneous approach can be recommended in situations with small or single tooth or self-containing bone defects (dehiscence or fenestration defects). A staged approach is preferred whenever a bone defect does not allow correct placement of an implant in the correct 3D position, where there is a large defect that requires an augmentation beyond the existing bony envelope, or if the bone defect has a vertical component exceeding 1-2 mm.[5] Adequate soft tissue conditions should always be present to ensure successful and predictable coverage of the graft.

Several bone grafting materials and membranes are available to choose from depending on the specific situation and defect. Autogenous bone remains the gold standard due to its biocompatibility, osteogenic, osteoconductive, osteoinductive properties. Use of membranes is important especially when using particulate bone grafting substitutes. Using growth factors (i.e. BMP) may lead to improved outcomes. Resorbable membranes are easier to use and will offer the least complications.

Non-resorbable membranes generally offer the best width gains provided that soft tissue healing achieved and maintained during graft maturation[6] however, non-resorbable membranes are known to involve high rates of complications. Premature exposure of a non-resorbable membrane may necessitate its removal along with the graft and the implant.[6] The success of bone augmentation is usually dependent on primary wound closure. Soft tissue dehiscence's can interfere with the healing of block grafts, thus promoting resorption and complete loss of the graft.[5] To avoid such undesirable adverse outcomes, it is mandatory to use surgical techniques that will guarantee primary soft tissue closure over augmentation sites. Factors that may increase the risk of wound exposure include: the width of keratinized mucosa;

flap thickness; flap tension; vestibular depth; type and size of the bony defect; and materials used.[10]

Lastly, there should be no reason for a clinician to withhold from their patients useful procedures of bone augmentation merely because they personally lack the skills to conduct these procedures on there own. It is better to refer a patient than to accept a compromise that may be limiting to the restorative outcome.[5]

## Can I apply the results in my practice?

The therapeutic effectiveness of ridge augmentation and implant therapy may be affected by risk factors and limitations such as, smoking, systemic conditions, dental status, the extent and location of the bone defect, anatomical limitations, patient preferences, budget constraints and reluctance to undergo major surgical procedures or acceptance of bone substitutes.[5] Clinicians should give careful consideration to these issues before deciding whether to incorporate a particular piece of research evidence into clinical practice. Use of CBCT scanners for pretreatment planning allows clinicians to anticipate more confidently whether a simultaneous or staged approach should be taken.

## Do benefits outweigh the potential harms and costs?

It is important to consider the burden to patients, such as donor site morbidity in hard and soft tissue grafting, and to pay attention to appropriate indications and correct choice and use of grafting materials to avoid overtreatment.[11] To reduce morbidity and complications and reduce costs it is always best to select a treatment strategy that will offer the least amount of surgical invasiveness. The simultaneous approach is less burdensome, costly and time-consuming compared to the staged approach. In both approaches there is potential risk of membrane or graft exposure, graft shrinkage or partial resorption. However with the simultaneous approach, postoperative wound infection or wound dehiscence may result in surface exposure of an implant and loss of the bone graft. This adverse event may turn out untreatable and require a second intervention for implant removal.[5]

## Clinical resolution

The meta-analysis showed that different ridge augmentation strategies were effective at gaining alveolar bone width in both the simultaneous and staged approach, although width gains were slightly higher for the simultaneous approach (WMD = 4.28mm) compared the staged approach (WMD = 3.90mm).

Both treatment approaches demonstrated high survival and success rates (>95%) when implants were placed in these regenerated sites.

The evidence presented by this meta-analysis supports the use different bone replacement grafts, the use of barrier membranes and application of the biological principles of guided bone regeneration (GBR) with ridge augmentation techniques. The relative effectiveness of different ridge augmentation strategies is very relevant to clinical practice. However, due to the poor quality of the individual studies, the evidence could be compromised. Therefore, any clinical decisions regarding superiority or inferiority of ridge augmentation strategies or biomaterials should be interpreted with caution. An important finding in this meta-analysis is that for both the simultaneous as well as the staged approach, membrane and/or graft exposure was the most frequently reported adverse event. More importantly, significant higher bone width gains and defect height reduction were achieved in non-exposed compared to exposed cases. This highlights the importance of ensuring proper treatment planning, appropriate surgical technique and application of biomaterials to ensure proper wound closure.

Well-designed RCT's are needed to determine the long-term efficacy of different ridge augmentation strategies, with specific focus on bone and soft tissue stability. These studies should also incorporate the use of adjunctive therapies such as platelet rich fibrin into ridge augmentation strategies to establish their effect on promoting healing and minimizing soft tissue dehiscence complications. Patient reported outcome measurements and aesthetic outcomes were seldom reported. Greater focus should be place on these outcomes in future studies.

## Disclosure and Disclaimer

Dr Johan Hartshorne is trained in clinical epidemiology, biostatistics, research methodology and critical appraisal of research evidence. This critical appraisal is not intended to, and do not, express, imply or summarize standards of care, but rather provide a concise reference point for dentists to aid in understanding and applying research evidence from referenced early view or pre-published articles in top ranking scientific publications and to facilitate clinically sound decisions as guided by their clinical judgement and by patient needs.

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