Localized Ridge Augmentation/Preservation.  
A Systematic Review

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Background: Osseointegrated implants have been documented as efficacious, however, their placement may be contraindicated in some patients due to insufficient bone volume. Techniques such as guided bone regeneration (GBR), immediate implantation, and distraction osteogenesis (DO) have been utilized as ridge enhancement therapies.

Rationale: This systematic review evaluates dental implant survival rates in patients treated with ridge augmentation or preservation techniques.

Focused Question: In patients requiring dental implant placement, what is the effect of localized ridge preservation versus implant placement without augmentation on implant survival and adverse effects?


Selection Criteria: Publications reporting survival rate of dental implants following ridge therapy were included in the analysis. Reports describing techniques were excluded.

Data Collection and Analysis: Due to the absence of controlled studies, a meta-analysis was not performed. Descriptive statistics are used to report the data.

Main Results
1. A total of 18 studies were included: 13 reporting on guided bone regeneration (GBR, 1,741 patients) and 5 on distraction osteogenesis (DO, 92 patients).
2. There is a high level of predictable implant survival in sites treated by GBR or DO.
3. These survival rates are similar to those of implants placed in native bone.

Reviewers’ Interpretations: Survival rates were similar for both GBR and DO implants. These survival rates were similar to implants placed in native bone.


KEY WORDS
Alveolar ridge augmentation; guided bone regeneration; dental implants: osteogenesis, distraction; review literature; comparison studies.
volume increases, longer and wider implants can be utilized. In addition, the idealized ridge can afford a proper emergence profile which optimizes esthetics and a restoration that is less difficult to fabricate.

The methodologies utilized to reconstruct the alveolar ridge have varied and include reconstruction with extraoral block autogenous grafts and treatment of localized alveolar defects, which require less invasive techniques. Currently, guided bone regeneration utilizing a barrier membrane covering an autogenous graft has been considered the standard of care. In addition, many investigators have found that grafts placed with barrier membranes have lower amounts of resorption. Clinicians commonly use autografts, allografts, and xenografts, as well as synthetic compounds. Overall, the perception of the clinician has been that ridge augmentation is successful. However, the efficacy parameters and documentation used have varied or were incomplete. Since the purpose of an augmentation procedure is to have sufficient bone for the placement of a dental implant, a logical outcome would be the survival rate of fixtures placed in regenerated bone compared to dental implants placed in native bone. The purpose of this systematic review is to evaluate dental implant survival rates in patients who have been treated with ridge augmentation or preservation.

RATIONALE
This systematic review evaluates dental implant survival rates in patients treated with ridge augmentation or preservation techniques.

FOCUSED QUESTION
The review was intended to answer the following focused question: 

“In patients requiring dental implant placement, what is the effect of localized ridge preservation versus implant placement without augmentation on implant survival and adverse effects?”

SEARCH PROTOCOL
Data Sources and Search Strategy
The MEDLINE and Cochrane Oral Health Group databases were utilized to search for studies. The search strategy developed included the following terms: dental implants; endosseous implants; dental implantation; guided bone regeneration; bone regeneration; guided bone augmentation; ridge augmentation; human; English; socket or ridge preservation; immediate implantation; growth factors; distraction osteogenesis; ridge splitting or ridge expansion.


Selection Criteria
The systematic review protocol defined the inclusion criteria for study eligibility. All study types were considered due to the absence of randomized controlled trials. The populations (subjects) were patients with inadequate bone to insert a dental implant who were treated by localized ridge augmentation/preservation utilizing various techniques and materials. Reports describing techniques were excluded.

Outcomes
The type of outcomes assessed were: primary outcome: implant survival rate; secondary outcomes: implant survival rate and change in bone height/width; patient-centered outcome: functional dental implant status; adverse outcomes: membrane exposure, reduced results, and effects of smoking. The review also attempted to determine the time of follow-up after implant placement.

Data Collection and Analysis
Following the database and hand searches, 2 reviewers (JPF, MLN) screened the titles and abstracts. An appraisal form for data abstraction was utilized and included: Intervention (e.g., guided bone regeneration); number of patients; implant success rate (percent); implant survival rate (percent); Length of follow-up (months); study type (e.g., prospective, retrospective); change in height/width (millimeters); implant under functional load (percent); rate of membrane exposure (percent); effect of smoking on implant survival; and reduced results.

Agreement between the 2 reviewers was determined for the inclusion or exclusion of reports. Due to the absence of controlled studies, a meta-analysis was not performed. Descriptive statistics were utilized to report the data. In order to standardize and clarify ambiguous data, dental implant survival was reported for each publication.

Ranking of Studies

MAIN RESULTS
The search strategy of MEDLINE and Cochrane databases found 530 and 36 publications respectively. Hand-searching revealed an additional one publication. A total of 37 studies were identified by the reviewers for data abstraction. The data collection indicated that 18 of the 37 articles could be analyzed. These 18 studies were stratified into 2 different interventions: guided bone regeneration (13)7-19 and distraction
osteogenesis (5)\textsuperscript{20-24} (Tables 1 and 2).\textsuperscript{7-23} The only consistent outcome variables for the analysis were implant survival rate and length of follow-up time. The study populations in the 18 publications range from 7 to 440. Distraction osteogenesis, a more recently described technique, had a mean sample population of 17.4 patients compared to the more established GBR therapies, which had a mean of 133.9. This trend was also observed when comparing the length of the follow-up periods. The mean ±SD observation time (months) for DO (18.6 ± 19.4) was less than GBR (56.5 ± 25.5). When the primary outcome variable was evaluated, the mean ± SD percent implant survival rate for GBR (95.8 ± 5.3) was similar to DO (97.2 ± 4.2).

**DISCUSSION**

The systematic review process revealed several potential interventions including traditional guided bone regeneration and more recent therapies such as immediate implantation and distraction osteogenesis. The search strategy focused question attempted to evaluate an outcome of implant survival, which had clinical reality. Specifically, was there evidence that an intervention could not only produce sufficient bone to support a dental implant but also that the implant would be successful? Traditional studies in implant dentistry have been centered on success/survival rate in native bone. Many of these investigations have been undertaken to generate product-specific data. As a result, these studies have defined characteristics of a large case-series study without a control group. In contrast, the developments in the areas of guided bone regeneration, immediate implantation, and distraction osteogenesis have been motivated by the clinician who desires a more predictable outcome for the patient. The studies in this area are numerous as indicated by the data from the search strategy. Unfortunately, the vast majority of these studies describe techniques and not the outcome of implant survival. In addition, inadequate study designs, primarily in the areas of data analysis and interpretation, limit the utility of many investigations. As a result, in this systematic review, the data analysis was limited to survival rate and observation period.

**Guided Bone Regeneration**

Over the past decade, guided bone regeneration has been refined to a level where dental implant placement and an optimal position is possible. Preclinical and clinical research has documented the efficacy of various techniques and materials,\textsuperscript{24-25} although most clinicians concur that a barrier membrane covering autogenous bone is the standard of care. However, in many cases the limitation with autogenous bone harvest directs the practitioner to utilize allografts or xenografts. The systematic search in the area of GBR resulted in 13 publications with sufficient information to provide data for analysis (Table 1). Overall, implants inserted in a site where bone was regenerated were predictable. In general, these studies were conducted in private offices enhancing the applicability of the results to the practitioner. Several publications noted in the review had survival rates above 96\%.\textsuperscript{11,13,16} Of these reports, Brocard et al.,\textsuperscript{16} Nevins et al.,\textsuperscript{13} and Fugazzotto et al.\textsuperscript{11} provide extensive data with survival rates of 92.5\%, 97.5\%, and 97.6\%, respectively. In these publications, study samples ranged from 331 to 440 patients. Investigations by Dahlin et al.,\textsuperscript{7} Jovanoic

### Table 1.

**Studies on Guided Bone Regeneration**

<table>
<thead>
<tr>
<th>Reference</th>
<th>N Patients</th>
<th>Survival Rate (%)</th>
<th>Observation Period</th>
<th>Study Design</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dahlin et al.\textsuperscript{7} 1991</td>
<td>6</td>
<td>100</td>
<td>36</td>
<td>CS II-3</td>
<td></td>
</tr>
<tr>
<td>Jovanovic et al.\textsuperscript{8} 1992</td>
<td>11</td>
<td>100</td>
<td>12</td>
<td>CS II-3</td>
<td></td>
</tr>
<tr>
<td>Buser et al.\textsuperscript{9} 1996</td>
<td>9</td>
<td>100</td>
<td>60</td>
<td>CS II-3</td>
<td></td>
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<tr>
<td>Cosci &amp; Cosci\textsuperscript{10} 1997</td>
<td>353</td>
<td>99.5</td>
<td>84</td>
<td>CS II-3</td>
<td></td>
</tr>
<tr>
<td>Fugazzotto et al.\textsuperscript{11} 1997</td>
<td>331</td>
<td>97.6</td>
<td>51</td>
<td>CS II-3</td>
<td></td>
</tr>
<tr>
<td>Mayfield et al.\textsuperscript{12} 1998</td>
<td>7</td>
<td>100</td>
<td>24</td>
<td>CT II-2</td>
<td></td>
</tr>
<tr>
<td>Nevins &amp; Mellonig\textsuperscript{13} 1998</td>
<td>352</td>
<td>97.5</td>
<td>74</td>
<td>CS II-3</td>
<td></td>
</tr>
<tr>
<td>Becker et al.\textsuperscript{14} 1999</td>
<td>51</td>
<td>85.7</td>
<td>60</td>
<td>CS II-3</td>
<td></td>
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<tr>
<td>Lorenzoni et al.\textsuperscript{15} 1999</td>
<td>63</td>
<td>100</td>
<td>24</td>
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<td></td>
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<tr>
<td>Brocard et al.\textsuperscript{16} 2000</td>
<td>440</td>
<td>92.5</td>
<td>84</td>
<td>CS II-3</td>
<td></td>
</tr>
<tr>
<td>Corrente et al.\textsuperscript{17} 2000</td>
<td>29</td>
<td>91.7</td>
<td>76</td>
<td>CT II-2</td>
<td></td>
</tr>
<tr>
<td>Brunel et al.\textsuperscript{18} 2001</td>
<td>14</td>
<td>86</td>
<td>84</td>
<td>CS II-3</td>
<td></td>
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<tr>
<td>Zitzmann et al.\textsuperscript{19} 2001</td>
<td>75</td>
<td>95.8</td>
<td>60</td>
<td>CT II-2</td>
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<tr>
<td>Mean ± SD</td>
<td></td>
<td>95.8 ± 5.3</td>
<td>56.5 ± 25.5</td>
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</tr>
</tbody>
</table>

* Maximum in months.
et al.,8 and Buser et al.8 demonstrate survival rates of 100%. However, these reports could be considered case series due to the limited sample size and follow-up period. With 3 exceptions, Mayfield et al.,12 Zitzmann et al.,19 and Corrente et al.,17 none of the studies included a control group. Mayfield et al. found no difference in implant survival with or without GBR.12 Zitzmann et al. reported a 1.5% greater survival rate in the control group compared to GBR.19 Corrente et al. evaluated implant survival in a controlled study comparing implants placed in regenerated versus native bone in 29 patients over maximum observation periods of 76 months (regenerated bone group) and 82 months (native bone group). These investigators demonstrated a survival rate in the GBR group of 92.3% as compared to 98.3% in native bone.17 Two publications, Becker et al.,14 and Brunel et al.,18 had a lower survival rate of 85.7% and 86%. These reduced the survival rate for GBR. Overall, the data analysis from this review indicates that dental implants in regenerated bone are successful. Further analysis of the publications regarding membrane, graft, or study types could not be completed due to insufficient data.

The dental surgeon has increasingly utilized immediate implant insertion due to the reduced time to complete a case. In a retrospective study, Cosci and Cosci found that the immediate placement in 353 patients resulted in a dental implant survival rate of 99.5%.10 The follow-up period was up to 84 months. The survival rate for immediately placed implants may be attributed to placement of the implant in native bone. The influence of extraction socket size and shape may also be a cofactor for survival of the implant.

**Distraction Osteogenesis**

The challenges of vertical augmentation have led to the application of distraction osteogenesis (DO) as a part of ridge augmentation therapy. In this therapy, a segmental osteotomy is created and the bone is moved by activation of a distractor. The systematic review revealed a limited number of studies that reported dental implant survival rates following distraction.20-24 In these reports, study populations ranged from 8 to 35 subjects, with a shorter evaluation time when compared to GBR. As a clinical outcome, linear gain was striking in these 5 investigations with a mean of 7.45 mm. McAllister reported a mean vertical augmentation of 3.14 mm with demineralized freeze-dried bone allograft and 5.02 with autograft.27 In a subsequent publication, Simion et al. also reported a dental implant survival rate of 97.5% following a 1- to 5-year follow-up period of 123 implants.28 Tinti et al. reported a mean vertical augmentation of 4.95 mm.30

**Augmentation Techniques**

The placement of dental implants in augmented/preserved sites can also include ridge splitting/expansion techniques and vertical bone ridge augmentation. Due to the limited data sets, an analysis of implant survival rates and follow-up period could not be completed. Two publications reported dental implant survival rate following ridge splitting/expansion.25,26 Engelke et al. placed a total of 121 implants in 44 patients in conjunction with the ridge-splitting procedure. Subjects were followed for up to 34 months with a survival rate of 90.3%.25 Scipioni et al. reported a dental implant survival rate of 98.5% in 170 patients who were treated with a ridge-splitting procedure.26 Another challenging area of clinical interest has been the vertical augmentation of the deficient ridge. The systematic review identified 2 clinical groups with 4 publications.27-30 The publications detail techniques involving various barrier and graft materials. Simion et al. reported a mean vertical augmentation of 3.14 mm with demineralized freeze-dried bone allograft and 5.02 with autograft.27 In a subsequent publication, Simion et al. also reported a dental implant survival rate of 97.5% following a 1- to 5-year follow-up period of 123 implants.28 Tinti et al. reported a mean vertical augmentation of 4.95 mm.30

**Table 2.**

<table>
<thead>
<tr>
<th>Reference</th>
<th>N Patients</th>
<th>Distraction Height Achieved</th>
<th>Implant Survival Rate (%)</th>
<th>Observation Period</th>
<th>Functional Load</th>
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<tbody>
<tr>
<td>Gaggel et al.20 2000</td>
<td>35</td>
<td>4.97 mm</td>
<td>100</td>
<td>9</td>
<td>Yes</td>
</tr>
<tr>
<td>Chiapasco et al.21 2001</td>
<td>8</td>
<td>8.5 mm</td>
<td>100</td>
<td>12</td>
<td>Yes</td>
</tr>
<tr>
<td>Rachmiel et al.22 2001</td>
<td>14</td>
<td>10.3 mm</td>
<td>95.6</td>
<td>6</td>
<td>No</td>
</tr>
<tr>
<td>McAllister23 2001</td>
<td>7</td>
<td>7.0 mm</td>
<td>100</td>
<td>13</td>
<td>Yes</td>
</tr>
<tr>
<td>Jensen et al.24 2002</td>
<td>28</td>
<td>6.5 mm</td>
<td>90.5</td>
<td>53</td>
<td>Yes</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td></td>
<td>96.5 ± 4.5</td>
<td>20.0 ± 22.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Maximum in months.
Augmentation of the deficient ridge has been accomplished with the growth factor, recombinant human bone morphogenetic protein-2 (rhBMP-2), by Howell et al.\textsuperscript{31} and Cochran et al.\textsuperscript{32} reported utilizing rhBMP-2 in a total of 12 patients. These studies of local ridge preservation and augmentation utilized a 0.43 mg/ml rhBMP-2/absorbable collagen sponge (ACS) device. The clinical results suggested that the device was well tolerated locally and systemically, with no adverse events. The rhBMP-2/ACS was easy to handle and could be adapted to the ridge or extraction site. Cochran et al. reported a dental implant survival rate of 100% over a 3-year follow-up period.\textsuperscript{32} Ridge preservation with rhBMP-2 has also been evaluated. In a recent randomized controlled masked study, Fiorelli et al. reported on buccal wall defects following tooth extraction treated with rhBMP-2/ACS, ACS alone, or no graft (unpublished data). Results from the 1.5 mg/ml group had significantly more bone formation than the ungrafted or ACS-alone treated groups. Dental implant success in the rhBMP-2 group had similar success rates to native bone after 3 years in function, whereas implants were not able to be placed in the ungrafted negative control sites (unpublished data).

**REVIEWERS’ CONCLUSIONS**

The survival of dental implants in the ridge therapies identified by the systematic review indicated a high level of predictability and similar to implants placed in native bone. However, the literature did not contain several data categories, which could be important in clinical decision-making. One area of interest would be the survival rate of augmentation in the GBR therapies. Although the implant survival rate demonstrated predictability, the GBR could be lower. This would have a negative impact on patient outcomes. The included studies also did not provide data on replacement fixtures, implant dimensions, and surface types. All of these factors could influence survival rates.

**REFERENCES**

Dental Implant Survival in the Augmented Ridge

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INTRODUCTION

The Consensus Report represents a collaborative effect of the Section members. The preparation of the report prompted considerable assessment of the localized ridge augmentation/preservation systematic review. The Section members recognize that the outcome of implant success following ridge augmentation therapy is important to the patient as well as the clinician. The discussions and decisions reflected agreement in this area. In addition, Section participants also discussed techniques that lead to the placement of dental implants. Although many studies document the efficacy and importance of these procedures, many do not report dental implant survival and success. In addition, in studies that report on dental implant survival and success in augmented bone, the success rate of the augmentation procedures used are not presented. Procedures including socket bone augmentation and immediate implant placement are predictable and should be a component of patient care.

1. Does the Section agree that the evidence-based systematic review is complete and accurate?

Yes. The Section members found that the reviewers were thorough and complete in assimilating a systematic review of evidence-based data for localized ridge augmentation. The following additions were determined relevant by the Section.

The definitions of success and survival vary between studies. The Section members recommend the following definitions be adopted and be considered for inclusion in the next edition of the Glossary of Periodontal Terms.

Implant success: The longevity of the dental implant in function regardless of status.

Implant survival: The quality of implant function and esthetics according to the criteria of Albrektsson et al. as modified and published in the AAP position paper on “Implants in Periodontal Therapy.”

2. Has any new information been generated or discovered since the evidence-based search cut-off date?

Yes, two additional publications that provide supportive information have been identified.

In a systematic review, Hämerle et al. found that studies reporting dental implant survival in regener-
ated bone were similar to dental implants placed conventionally into sites without the need for bone augmentation.7

In a recent randomized controlled masked study, Fiorellini et al. (unpublished data) reported on buccal wall defects following tooth extraction treated with rhBMP-2/absorbable collagen sponge (ACS), ACS alone, or no graft. Results from the 1.5 mg/ml group had significantly more bone formation than the ungrafted or ACS alone treated groups. Dental implant success in the rhBMP-2 group had similar success rates to native bone after 3 years in function, whereas implants were not able to be placed in the ungrafted negative control sites (unpublished data).

3. Does the Section agree with the interpretations and conclusions of the reviewers?
The Section members found the interpretations and conclusions of the reviewers thorough and accurate.

4. What further research needs to be done relative to the focused questions of the evidence-based review?
While the Section realizes the value of additional well-designed cohort studies or RCTs for the evaluation of various ridge augmentation materials and techniques, the challenges and multifactorial nature of these studies encouraged the Section members to limit recommendations for further research to the following:

While no absolute contraindications exist in the literature, it would be beneficial to evaluate implant success as it relates to potential risk factors such as: membrane exposure, primary flap closure, initial implant stability, graft containment, periodontal disease, occlusal loading, smoking, and other systemic and behavioral factors.

Studies are needed to determine if multiple grafting procedures or techniques are required in the treatment of some bone defects to optimize the esthetic and functional outcome of implant reconstruction.

Studies are warranted to evaluate tissue-engineering techniques (e.g., molecular, cellular, and genetic) that may reduce the time required prior to prosthesis delivery and may enhance bone quality and quantity.

5. How can the information from the evidence-based review be applied to patient management?
The field of implant dentistry is a critical component of patient care. Success of dental implants in native bone has strong evidence to support their use. The development of techniques and materials for localized ridge augmentation has evolved to a point that there is evidence to support several types of augmentation procedures.

A. Socket bone augmentation. There is evidence to support the use socket bone augmentation for localized ridge augmentation. Dental implants placed at sites augmented by this method are successful under functional loads.

Level of Evidence:8 Moderate.

Rationale: Assignment of a “moderate” level of evidence is based on 1 level I RCT and 5 level II-3 case series studies.

B. Horizontal Bone Augmentation. There is evidence to support the use of horizontal bone augmentation techniques (e.g., simultaneous and staged bone augmentation) to achieve dental implant success rates similar to those when the implants are placed in native bone.

Level of Evidence: Moderate.

Rationale: Assignment of a “moderate” level of evidence is based on 3 level II-2 and 10 level II-3 studies.

C. Vertical Bone Augmentation. There is some evidence to support the use of vertical bone augmentation techniques (e.g., simultaneous and staged bone augmentation and distraction osteogenesis) in achieving successful dental implants.

Level of Evidence: Limited.

Rationale: Assignment of a “limited” level of evidence is based on 2 level II-2 and 7 level II-3 case reports.

REFERENCES


