Dental Implants in AUBB and ALBBs

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The Implant survival rates were negatively affected in sub-entities linked to more extensive augmentation procedures such as bone donor site and dentition status. The inclusion and pooling of literature with a low level of evidence, the absence of randomized controlled clinical trials (RCTs) comparing AUBB and ALBB and the limited count of comparative studies with short follow-ups increases the risk of bias and complicates data interpretation.

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1. Introduction

Contemporary implant-borne prosthetics represent the benchmark for dental restorations regarding both aesthetics and improvements in the quality of life [1][2]. However, prolonged edentulism, periodontal disease, tumor and cyst resection, trauma and/or infection may cause severe bone loss and render implantation inaccessible [3][4]. Despite several implant-associated innovations, including the development of materials with greater Young's modulus than conventional titanium [5], implant surface modification [6] or the introduction of narrow and short implants [7], pre-implant bone regeneration is often inevitable, as emphasized by an analysis of 10,158 implants which revealed a bone grafting frequency of 58.2% [8]. Various grafting materials and techniques have been introduced to restore lost bone tissue and facilitate implantation, and former comparative studies have reported similarly favorable outcomes for implants in pristine or augmented bone; however, one study found implant survival rates (ISRs) of 90% for implants in native bone and 79% for implants in grafted bone following ten years of healing [9], whereas others have reported cumulative ISRs of 94.1% for implants in native and 100% for those placed in grafted bone [10].

Grafting materials with the intrinsic capacity of producing new bone tissue via vital osteoblasts are called osteogenic, whereas grafting materials stimulating the differentiation of progenitor cells into osteogenic cells, which is most frequently mediated by growth factors such as bone morphogenetic protein-2, have osteoinductive properties, and materials solely functioning as a scaffold by stabilizing the defect area and providing structural support for new bone formation are termed osteoconductive [11]. Autogenous bone grafts exhibit all three characteristics, whereas most commercially available bone substitute materials are only osteoconductive [12]. The most obvious disadvantage of autogenous bone grafts is the bone harvesting procedure and the associated donor site morbidity, whereby harvesting from extraoral sites, including the iliac crest, is associated with a considerably increased risk of complications and patient burden as compared to bone harvesting from intraoral sites, especially the ramus [13][14][15]. In this context, pain score analysis of patients enrolled in a study comparing bone augmentation carried out with autogenous bone blocks (AUBBs) and allogeneic bone blocks (ALBBs) was in favor of patients who were treated with ALBBs and was concomitant with a higher willingness to undergo the procedure again [16].

Allografts are manufactured from deceased or living human bone donors, which were established to combat the challenges of availability and harvesting of autogenous bone and donor site morbidity [17]. Due to their physicochemical properties, which widely resemble those of autografts, and similar clinical outcomes, allografts have been proposed to represent the best option for autografts [18][19]. Implant dehiscence and minor horizontal bone defects are predictably restorable with various granular bone substitute materials in most instances, whereas the treatment of complex osseous defects spanning multiple teeth or entire jaws requires extensive measures such as titanium meshes or block bone grafts [20]. Regarding the application of solid bone blocks, solely allogeneic bone blocks (ALBBs) have been demonstrated to result in comparably favorable outcomes to autogenous bone blocks (AUBBs), whereas clinical data of xenogeneic or alloplastic block grafts are vastly limited and generally discourage their application [21][22][23]. In a previous review, Nevins et al. reported an ISR of 97.5% for 526 implants followed from 6 to more than 74 months post-loading, irrespective of the application of autogenous or allogeneic bone blocks [24].

2. Implant Survival Rate

The survival of implants within grafting materials is probably the most crucial analysis, because the main purpose of bone grafting procedures is dental rehabilitation, which should last decades, and ideally, a lifetime. As for AUBB, two studies reported implant survival rates (ISRs) below 80% for cortico-cancellous iliac grafts with simultaneous [25] and delayed implants [26] in the maxilla, and both studies included totally edentulous patients. Both authors reasoned the loss of implants with marginal bone resorption, which was demonstrated to be increased within the first three years. Astrand et al. concluded that proceeding with the resorption of AUBB, especially with grafts exhibiting large amounts of cortical bone, which is impervious to vascular infiltration, is one major challenge for the predictability and the long-term success of implants in AUBB [25]. In this context, Molly et al. reported a significantly decreased marginal bone resorption of less than 1 mm associated with implants inserted into bone which was regenerated via titanium foil without a grafting material when compared to the marginal bone loss of implants placed in cortico-cancellous AUBB, which was 2.7 mm after 20 years, and hence demonstrated ongoing block resorption [26].

A cohort study comparing the survival of implants placed in jaws augmented with cortico-cancellous iliac blocks covered by an RCM (resorbable collagen membrane) alone or by an RCM combined with deproteinized bovine bone mineral (DBBM), reported ISRs of 99.2% and 98.8%, respectively, but due to the significantly lower resorption the authors observed in the DBBM group, they reasoned that graft covering with non-resorbable materials might be beneficial regarding long-term outcomes, whereby follow-up in this study did not exceed 24 months; thus, this was insufficient for a definitive conclusion [27]. A previous study of the same group reporting a 91.5% 5-year implant survival rate with uncovered iliac grafts which emphasized their conclusion [28]. Additionally, Tunkel and De Stavola made similar observations when covering augmentation sites restored via the shell technique with DBBM at the time of implant insertion, which they established as the “delayed relining technique” [29]. In contrast to these findings, an RCT reported 2-year ISRs of 100% for a cohort receiving uncovered AUBB, but also AUBB covered with DBBM and an RCM, whereby the authors described higher complication rates associated with the application of barrier materials [30]. Two RCTs reported slightly reduced ISRs within cortico-cancellous chinbone [31] and ramus [32] grafts covered with DBBM and an RCM as compared to uncovered grafts, whereby the authors of both studies stated that all applied augmentation techniques resulted in comparably favorable outcomes. In the analysis, researchers also found an increased implant failure rate for implants inserted into relined AUBB as compared to blocks covered only by an RCM ($p = 0.021$); however, the ISR of uncovered AUBB was lower than that of grafts covered by membranes and/or granular materials, whereby the difference was not statistically significant ($p = 0.071$). One important issue might be the difference between graft relining and graft overcontouring. Relining is based on a thin layer of volume-stable grafting material, whereas overcontouring marks the extending of the graft beyond the bony envelope, which has been demonstrated to be accompanied by increased complication rates [33]. Further controlled cohort studies with long-term follow-up should investigate the impact of graft relining.

Regarding the relevance of the bone donor site and the patient's dentition, Raghoebar et al. reported an ISR of 100% for partially edentulous patients receiving cortico-cancellous AUBB harvested from intraoral sites, whereas an ISR of 95.6% was found for totally edentulous patients treated with bone blocks from the iliac crest [34][35]. These findings strongly correlate with the results from the statistical analysis, which demonstrated significantly increased ISRs in grafts harvested from intraoral as compared to extraoral donor sites, and likewise, in grafts harvested from the ramus as compared to those harvested from the iliac crest. The significantly increased ISR calculated for cortical as compared to cortico-cancellous AUBB is strongly linked to these findings because, other than cortico-cancellous iliac grafts, ramus grafts are mostly monocortical. Totally edentulous patients are more often subjected to bone augmentation with grafts harvested from extraoral donor sites than partially edentulous patients; therefore, ISRs calculated for implants in partially edentulous patients were significantly increased. In this context, the significantly lower ISRs of implants in AUBB determined for patients older than 45 as compared to those of younger patients may, on one hand, result from age-related causes, but also from the extensive crossover of this dataset with that of the totally edentulous group. Statistical analysis indicated a significantly lower ISR for immediate implants as compared to delayed implants placed within five months of healing, but not as compared to implants inserted following six or more months of graft consolidation, which makes sense considering that extraoral bone grafts have prolonged healing times and, hence, are stronger represented in the late implantation group, whereby some authors reported similar ISRs for immediate and delayed implants [36][37][38].

Implant survival rates in all studies associated with the application of ALBB were above 90%, whereby the lowest survival, which mainly resulted from insufficient primary implant stability, was reported for implants inserted into FFBA onlay blocks applied without resorption barriers [39]. The second lowest ISRs of 94.03% were also reported for cortico-cancellous FFBA blocks. The inclusion of full-arch reconstructions, and thus, complex bone augmentations with extensive bone volumes, for which statistical analyses of AUBBs already indicated lower ISRs as compared to segmental reconstructions in partially edentulous patients, is one putative reason for the rather low ISRs reported in this study [40]. Studies reporting results associated with totally edentulous patients were exclusively conducted with FFBA, and 90% of these included vertical defects, for which the analysis indicated a significantly lower ISR as compared to implants inserted in ALBB applied for horizontal bone defects. This, in turn, provides an explanation for the significantly increased ISR found for processed bone allografts (PBAs) as compared to FFBA blocks. In two independent studies by the same authors, ISRs of 98.3% and 96.3% were reported for cortico-cancellous and cortical FFBA block grafts, respectively [41][42], whereas other authors reported 2-year ISRs of 100% for cortico-cancellous and cortical FDBA blocks alike [43], which further emphasizes the results of the statistical analysis in this research. Nissan and Chaushu also analyzed survival rates of up to three years for implants inserted into cancellous FDBA blocks, which ranged from 95.2% for restored congenitally missing teeth in the maxilla, whereby only one immediately loaded implant failed [44], to 100% for implants inserted into the augmented anterior mandible [45].

Regarding comparative cohort studies, Al-Abedalla et al. reported similar ISRs for implants in native bone, AUBB and ALBB; additionally, the authors found striking similarities in the tissue composition in histologic specimens of pristine bone and specimens recovered from the augmented area [46]. Chiapasco et al. found 100% 2-year ISRs for cortico-cancellous AUBBs applied for full-arch reconstructions in the maxilla, whereas the ISR of the cohort treated with cortico-cancellous FFBA blocks was 90.1% due to increased complications, graft exposure and uncontrollable resorption. The authors concluded that FFBA does not represent a safe alternative to AUBB [47], which they substantiated by a further study with corresponding results [47]. An implant survival rate of 100% was reported for implants inserted into both cortical AUBB and cortico-cancellous FFBA blocks applied for horizontal bone augmentations in two separate studies by the same authors [25][48], which emphasizes the feasibility of achieving similar results with AUBB and ALBB following the regeneration of horizontal bone defects. An ISR of 100% for both cohorts was reported by all comparative studies on AUBB and processed allogeneic bone blocks. Kloss et al. compared the 1-year ISR of implants in cancellous FDBA blocks with that of AUBB harvested from the ramus for horizontal augmentations in single-tooth defects [49], whereas Park et al. reported 2-year ISR following vertical augmentations with cortical AUBB and cortico-cancellous FDBA [50]. Schlee et al. reported a 2-year ISR of 100% for implants inserted into either AUBB harvested from the ramus or pre-milled bone blocks made of cancellous solvent-dehydrated bone allograft used for the augmentation of three-dimensional bone defects [16].

The six comparative cohort studies [16][46][51][47][49][50] presumably represent the most valid source of contemporary information on the clinical performance of AUBB and ALBB; however, none of these was an RCT and three studies had a retrospective study design, which increases the risk of bias. The longest follow-up for allogeneic bone blocks in those comparative studies was limited to 32.9 months [16], i.e., less than three years. Additionally, the mean follow-up for studies reporting ISRs associated with ALBBs was only 25.1 ± 10 months. Regarding AUBB, the longest follow-up in comparative studies was 59.9 months [50]; additionally, the mean follow-up duration of 38.3 ± 36.7 months of studies reporting ISRs in AUBB notably exceeded that of ALBB. The scarce number of studies with long-term follow-up data represents another shortcoming in the interpretation and analysis of the present data, because only 1–2% of implants fail within the first months, whereas 5% of implant failures occur several years after successful osseointegration of the implant, mainly due to peri-implant disease [52]. Although some authors reported increased complication rates with allogeneic bone grafts, especially in vertical augmentations [53], the majority of clinical studies and previous reviews on this matter emphasize that ALBBs represent an adequate alternative to AUBBs, especially concerning processed bone allografts and horizontal bone regeneration procedures. An extensive analysis of complications occurring in 137 ALBBs by Chaushu et al. found 8% of total graft failures due to “membrane exposure”, “incision line opening”, “soft tissue perforations” and “recipient site infections” [54]. These failure items emphasize the most critical factor for success irrespective of the applied graft: proper soft tissue covering of the graft. One factor clearly favoring the application of ALBB over AUBB is the lower overall patient burden, because no bone harvesting is required. Several studies have reported complications associated with bone harvesting and a low willingness of patients to repeat the same procedure [15][55]. Although the complications are limited to temporary but also permanent nerve damages when bone is harvested from intraoral sites in most instances, more severe complications may occur with extraoral bone harvesting [56][57][58].

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