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The use of autologous bone for augmentation procedures leads to low prevalence of peri-implantitis—a retrospective study over a 20-year period

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ABSTRACT

The aim of this study was to compare the prevalence of peri-implantitis in implants inserted into pristine bone (control) to implants where autologous bone was used for grafting procedures (study).

All patients who underwent implant surgery during a 20 years interval by one maxillofacial implant surgeon and received a prosthodontic rehabilitation afterwards were eligible for inclusion in the study. Periimplant bone resorption and periimplant disease were assessed.

Of 421 patients 384 (91.2%) patients responded to a recall after having been treated over a 20-year period by one maxillofacial surgeon and several dentists. A total of 110 patients had 239 implants in pristine bone, and 274 patients had 607 implants placed in combination with autologous bone grafting procedures. Mean time in function was 74 months (range 15–236 months). In all, 342 implants (34.8%) were in function for longer than 7 years. A total of 64 implant sites (7.6%) in 39 patients (10.2%) showed signs of peri-implant mucositis. In addition, 17 implants (2.0%) in 14 patients (3.6%) revealed signs of peri-implantitis, of which five implants were in the control group (2.09%) whereas 12 implants were in the study group (1.98%), with no statistically significant difference ($p = 0.8405$). More than half of the patients with peri-implantitis had a history of periodontitis. Three implants were lost due to peri-implantitis and four implants failed for other reasons, resulting in an overall success rate of 99.2% in 846 implants.

Conclusions: Within the limitations of the study it seems that the use of autologous bone still is a relevant option when performing augmentation procedures because of the low prevalence of peri-implantitis.

1. Introduction

The introduction of osseo-integrated dental implants has revolutionized dentistry. They offer excellent solutions to many clinical situations in which the loss of teeth in the past was treated with less acceptable prosthetic solutions. However, the prevalence of peri-implant inflammatory diseases caused by oral bacterial biofilm is a major reason for complications and implant failures (Berglundh et al., 2018; Schwarz et al., 2018; Meyle et al., 2019; Salvi et al., 2019; Carcuac et al., 2020).

Peri-implant bone loss may not only lead to the loss of the implant and its supra-structure but may often damage the surrounding bony structures and secondarily also the soft tissues and neighboring teeth.

Although peri-implant mucositis is often reversible by conducting intensive hygienic measures, the bone loss due to peri-implantitis is difficult to treat successfully (Heitz-Mayfield et al.,

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2018a, 2018b). Thus the prevention of peri-implant diseases has become a priority in implant dentistry (Berglundh et al., 2019).

Reports on the prevalence of peri-implant diseases show a wide range with variations in case definitions and observation times, which sometimes are too short to be meaningful. They can be based on randomly selected population samples or even on convenience samples (Salvi et al., 2019).

A large important study documented, after 9 years, a prevalence of peri-implantitis in 14.5% of patients and in 8.0% of implants with bone loss of 2 mm or more after initial remodeling (Derks et al., 2016). A recent consensus report gives a subject-based weighted mean prevalence of peri-implantitis of 22% with a mean implant-based prevalence of 12.8%, ranging from 0.4% to 36.6%. The mean time in function for these data ranged from 3 to 11 years (Meyle et al., 2019) with many short observation periods.

The role of autologous bone grafting has not been addressed in these reports, although it is still considered to be the gold standard for reconstructing missing bone. In addition, there were disconcerting reports about complications from the donor sites of up to 31.6% (Al-Nawas and Schiegnitz, 2014; Thoma et al., 2019). The majority of these reports originate from dental clinics, whereas maxillofacial surgeons report much lower grafting complications (Chiapasco et al., 2008, 2020). However, most publications from maxillofacial surgeons report on extensive reconstructions after tumor ablations or for other large defects (Attia et al., 2018; Maiorana et al., 2019; Putters et al., 2019; Lodders et al., 2021) without looking specifically for the prevalence of peri-implantitis. No reports exist, to our knowledge, in which the consistent use of autologous bone for grafting procedures over a long time span was set into relation to the outcome regarding peri-implantitis. This study aimed at filling this knowledge gap.

2. Materials and methods

All patients who underwent implant surgery between 2000 and 2018 by one maxillofacial implant surgeon were listed independent of the type of surgery carried out. The prosthetic restorations were conducted by several general dentists with specialist training in implant prosthetics. Treatment planning had been undertaken together with the referring dentist based on the medical and dental history and after an assessment of the hard and soft tissues. Requirements to undergo implant surgery comprised good oral hygiene with no periodontal disease and no smoking. Careful consideration of each individual case had been given before surgery if patients had a history of periodontal disease, a history of smoking, were treated with anti-resorptive medication, steroids, or other medication that influences bone remodeling. In the individual consent letter, which every patient had signed before surgery, they were made aware of these issues and that they should see their dentist for yearly check-up and twice a year see the hygienist.

For this study, all implants were included with only one exclusion criterion: implants had to be loaded for at least 1 year.

Implants either were inserted into pristine bone without any additional grafting procedures (control group) or were inserted in combination with autologous bone grafting procedures (study group) to enable adequate implant position:

To augment the height and thickness of the alveolar bone; to fill bone defects; to smoothen out undercuts or similar bone defects, or to reconstruct missing bone parts and to perform sinus floor augmentation procedures. For single implants and up to three implants in the same region 0.1cc-0.5cc autologous bone was harvested from the vicinity of the insertion area, that is, mandible, maxilla, zygoma, nasal spine, maxillary tuberosity, or chin (*Local bone graft, LBG*).

If more than 0.5 cc of autologous bone was to be obtained for grafting, the region of the lower third molar/oblique mandibular crest was used for harvesting. For large single defects, for example, in the upper incisor region, bone blocks were used in its entirety, fixed with one or two osteo-synthesis screws, and covered with a dissolvable membrane (Bio-Gide, Geistlich Pharma AG, Wolhusen, Switzerland). For sinus floor augmentations, the blocks were cut into small pieces and parts of them milled with a bone mill (*Mandibular bone block graft, MBBG*).

If the necessary amount of autologous bone could not have been obtained from bilateral mandibular bone harvesting it was taken from the hip under general anaesthesia with 1 overnight stay in hospital *(Hip bone graft, HBG*) These patients presented with extreme atrophy of the maxilla needing extensive sinus floor augmentations as well as onlay/inlay bone blocks to the anterior maxilla or Le Fort I advancement procedures for bringing the maxilla into a position where fixed dental prostheses (FDP) could be placed in an adequate occlusal relation.

From all patients, the clinical notes, operating reports, and x-rays (pre- and post-operative periapical, Orthopantomograms (OPT's) CT's and CBCT's) were available. The following data could be retrieved from these: health data from the patients, including medication, periodontal history, oral surgery history including trauma, failed implants, infections, cysts etc; operation dates and time lapse until loading of the implants was carried out; any type of bone grafting procedure at the time of implant insertion and in case of two-stage procedures when and what surgery for bone grafting was undertaken before implant surgery; harvest site and amounts of harvested autologous bone (estimated intraoperatively in steps of 0–0.25 cc, up to 0.5 cc, and over 0.5 cc); augmentation type at the implant site (horizontal widening of the alveolar process, sinus floor augmentation, etc); implant manufacturers and implant types with all technical details, including length and width; reason, manufacturer, and amount in cubic centimeters and percentage for additional use of bone replacement materials, that is, for mixing it with autologous bone in some sinus floor augmentations; use of membranes, osteosynthesis screws, etc; intra- and post-operative complications encountered, which were classified according Clavien-Dindo (Dindo et al., 2004).

Having been discharged from the surgical service years ago, contact with all patients was sought with significant effort to prevent the possibility that a convenient sample or too small a sample would be investigated. Informed written consent had been obtained initially from all patients prior to treatment and was again obtained before the study examination. This entailed the purpose of the recall program with clinical examination, periapical radiographs, and the patients' authorization to use their anonymized data for statistical analysis and to publish the data. Ethical approval was obtained from the Ethics Committee, Clinical Trials and Research Governance of the University of Oxford (September 22, 2017). The study has been carried out in accordance with The Code of Ethics in the World Medical Association (Declaration of Helsinki). The patients gave an update on their general health, current medication, smoking habits, as well as frequency of visits to their dentists and hygienists.

Clinical and radiographic assessment were carried out by five independent investigators (including J.T.L., M.B. and F.C.). These assessors all had not been involved in the treatment planning or in the treatment. Authors involved in the treatment were excluded for the clinical and the radiographic assessments.

The clinical assessment comprised a general view of the mucosal and dental health, of probing of each implant at four aspects (mesial, distal, buccal, oral) with recording of the probing pocket depth (PPD), bleeding on probing (PoB), and any suppuration, swelling, redness and pain. The prosthetic supra-structure was

judged with regard to giving good access to cleaning, and any surplus of luting cement was noted. Keratinization was not measured but was recorded as absent, narrow (meaning below 2 mm) or wide (meaning 2 mm or more). The deepest probing depth measured around each implant was used in the statistical analysis. In addition, all harvest sites for autologous bone grafting were inspected. The scars after mandibular bone graft and hip bone graft sites were evaluated regarding possible functional impairment and aesthetic appearance.

For radiographic assessment, digital peri-apical X-rays in rectangular technique were obtained of each implant (Nomad, Aribex Inc, Utah, USA, processed with Digora DXR-60, Soredex, Inc., Finland) and bone levels measured at the mesial and distal aspects of the implants. Bone loss was calculated by comparing the measurements obtained at the assessment date with measurements of baseline radiographs, that is, radiographs obtained at the end of prosthetic rehabilitation and up to 24 months after prosthesis connection. If no baseline radiographs were available, a reference landmark for each implant system was used for the measurements at the mesial and distal aspects of the implants. The largest value of bone loss was recorded.

Peri-implant mucositis was defined as implant sites presenting with BoP/suppuration but no detectable bone loss.

Peri-implantitis was defined as implants sites presenting with BoP/suppuration and bone loss of 2 mm or more after crestal bone level changes resulting from initial bone remodeling had taken place.

Successful implants were those in function without mobility, pain, or dysesthesia and with less than 2 mm peri-implant bone loss at the end of the observation period.

Failed implants were defined as mobile or fractured implants, implants in patients with persistent paraesthesia or chronic pain, or in patients presenting continuous peri-implant bone loss not responding to medical/surgical treatment.

For statistical analysis, mean values with standard deviations and p values were computed for the entire cohort, for the control and the study group. The Kaplan-Meier method was applied for time in function to detection of peri-implantitis. Mean/median and proportions were calculated, respectively. Subgroup analyses were performed regarding the history of periodontal disease and for the time in function of the implants (1–60 months, 61–84 months, 85–120 months, over 120 months). The Fisher exact test was used for the comparison of the occurrence of peri-implantitis in implants inserted into pristine bone to implants for which bone augmentation procedures had been carried out.

3. Results

3.1. Patient-related data

Of 421 patients treated, 384 patients (229 female and 155 male) with 846 implants responded to the recall for clinical and radiographic assessment, resulting in a response rate of 91.2%. Seven patients were deceased, 25 patients could not be contacted, three patients were contacted but could not take part in the study, and two patients had delayed the prosthetic work and their implants had been loaded for less than one year. The patients' average age at the time of implant surgery was 51.6 years (range 16.5–91 years).

At the time of implant surgery, all patients were non-smokers: 360 patients (93.8%) were non-smokers in that they either never smoked or had given up smoking years before implant surgery. A total of 24 patients (6.2%) were smokers between 1 year and up to 6 months before implant surgery. Of these, 15 patients (3.9% of the study population) restarted smoking between 8 months and 4 years after implant surgery. Two of these patients reported smoking one and three cigarettes a day, respectively. However, these two patients were considered smokers at the time of the clinical investigation, resulting in 96.1% non-smokers at the time of the investigation.

A total of 26 patients (6.5%) had had periodontal disease in the past. Six patients (1.6%) reported taking oral bisphosphonate or other antiresorptive medication before implant surgery for osteoporosis of less than 4 years duration. All six patients had interrupted this medication for 6–12 months ("drug holiday") before surgery. Another six patients had been starting antiresorptive drug therapy for osteoporosis after completion of implant therapy. No patient had had antiresorptive medication for tumors. Three patients were taking cortisone intermittently when rheumatoid arthritis showed flare-ups. Four patients used methotrexate. Six patients had diabetes, which was well controlled by diet and oral medication. Five patients had a history of previous implant loss. In all, 82.5% of patients reported seeing the dentist at least once a year and the hygienist twice a year. A further 5.8% reported seeing the dentist irregularly but the hygienist once a year. Another 11.7% of patients reported longer time lapses, the longest being 7 years with neither a dental nor a hygienist visit.

3.2. Implant manufacturers and types, and loading protocol

Table 1 shows manufacturers and all types of implants used, including the respective diameters. In Table 2, the length of the implants is given. In all, 833 (98.7%) Straumann implants (Straumann AG, Basel, Switzerland) were used whereas 13 implants were from other manufacturers. These were seven Nobel Biocare implants (Nobel Biocare, Kloten, Switzerland), three Osseo Speed Astra implants (Astra Tech Implant System, Dentsply AB, Mölndal, Sweden), and three Biomet 3i implants (Zimmer Biomet, Palm Beach Gardens, FL, USA). Of the Straumann implants, 675 (81%) were tissue-level implants and 158 (19%) were bone-level implants. Loading was usually initiated 3 months after surgery. No implant was loaded immediately. Five implants were placed immediately after tooth extraction (together with autologous bone augmentation of the remaining alveolar gap), and loading was initiated after 3 months.

3.3. Observation periods

Of all implants 159 (18.8%) had been in function for longer than 10 years and 135 implants (16%) were in function for 7–10 years (Table 3). Thus, 342 implants (34.8%) were in function for longer than 7 years. Another 150 implants (17.7%) were loaded for 5–7 years, whereas 402 implants (47.5%) were in function for 1–5 years. The longest time that an implant was in function was 236 months (19.7 years).

3.4. Control and study group, bone grafting procedures

Whilst in the control group 239 implants (28.3%) in 110 patients (28.6%) were placed into pristine bone without further surgery, in the study group 607 implants (71.7%) in 274 patients (71.4%) needed bone grafting procedures to enable adequate implant position (Table 4). The procedures carried out and results are described below.

3.4.1. Local bone grafts (LBG)

A total of 218 patients received such a local bone graft for 429 implants (70.7%). Of these, 281 single implants (65.5%) were grafted with 0.1–0.25 cc autologous bone, and for another 148 implants (34.5%) 0.5 cc autologous bone could be obtained with this method. For buccal perforations in the region of the implant apex away from

Table 1
Implant manufacturers, types.

Manufacturer & Type	Quantity
Straumann Tissue Level	
3.3 NN S	5
3.3 NN SP	10
3.3 RN S	32
3.3 RN SP	133
4.1 RN S	139
4.1 RN SP	231
4.1 RN TE	3
4.8 RN S	20
4.8 RN SP	7
4.8 WN S	38
4.8 WN SP	55
4.8 RN TE	2
Straumann Bone Level	
3.3 NC	90
4.1 RC	68
Nobel Biocare	
3.75 Braenemark Mk III RP	3
4.0 Braenemark Mk III RP	4
Astra Tech (Dentsply)	
4.0 OsseoSpeed TX	3
Biomet 3i	
3.25 Osseotite	1
4.0 Osseotite	2
Sum	**846**

Table 2
Implant lengths.

Length (mm)	n
6	7
8	50
8.5	3
9	10
10	223
12	464
14	92
16	4
Sum	846

the implant shoulder, 0.1–0.15 cc additional bone substitutes (Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) were used in 28 of these 429 implants (6.5%). The implant shoulder and the cranial 4 mm of the implants received exclusively autologous bone. All but three of these patients were treated under local anaesthesia.

3.4.2. Mandibular bone block grafts (MBBG)

In all, 41 patients (15%) received 97 implants (16%) in regions augmented by mandibular bone graft. For 28 of these 41 patients, the mandibular bone block graft was used in its entirety, and undercuts and borders were smoothened with additional bone chips. In 5 cases, undercuts, away from the implant insertion areas, were filled by bone substitute. In all, 67 (69.1%) of the 97 implants were inserted into these blocks. They were always placed in a second stage 5–7 months after the grafting procedure. All but one of these patients were treated under local anaesthesia.

Table 3
Time in function and prevalence of peri-implantitis, all implants.

Time (months)	implants (n)	Peri-implantitis (n)	Peri-implantitis (%)
1–60	402	3	0.75
61–83	150	2	1.3
84–120	135	6	4.4
> 120	159	6	3.8

3.4.3. Hip bone graft (HBG)

In 15 patients (5.5%), the necessary amount of autologous bone was taken from the hip under general anaesthesia with 1 overnight stay in hospital. A total of 81 implants (13.3%) were placed in these 15 patients, always in a second-stage surgery and always under local anaesthesia. They received an average of 5.4 implants.

3.4.4. Sinus floor augmentation

A total of 91 patients (22.9%) underwent 106 sinus floor augmentation procedures with lateral window technique. For 76 patients, this was done on one side, whereas 15 patients underwent a bilateral procedure, usually at the same time. In all, 182 implants (30% of the 607 study group implants) were inserted into the grafted maxillary sinus floor; 93 implants (51.1%) were inserted at the time of the sinus surgery, whereas 89 implants (48.9%) were inserted in a second operation (two-stage procedure). The latter was necessary when the residual height of the alveolar bone was 4 mm or less. This was the case in 41 (45.5%) of the 106 sinus floor augmentations. The grafting material consisted for 75 surgeries (70.8%) with 134 implants of exclusively autologous bone, the source being for 27 augmentations local bone; for 19 augmentations the harvest site was mandibular bone; and for 28 augmentations it was hip bone. In 31 sinus floor augmentations (29.2%) with 48 implants, bone substitute was used to give additional volume to avoid the need for upscaling the bone harvest site: avoiding mandibular bone graft when the amount of local bone graft was not sufficient, avoiding bilateral mandibular bone graft when one side was not sufficient. or to avoid hip bone graft when the amount from bilateral mandibular bone graft was not sufficient. Either 0.25 cc or 0.5 cc was used, resulting in 75% or 50% autologous bone, respectively (Table 5). No sinus was grafted with exclusively bone substitutes. In 24 of these 31 augmentations, the remnant vertical height of bone was 2 mm or less. However, the actual floor of the sinus was grafted with exclusively autologous bone for the first 3 mm and then the mixture of bone/bone substitute was grafted cranially to this. In this way, any future bone loss due to remodeling or peri-implantitis would not reach a region where still foreign material might be present and the neck of the implant would remain in pure autologous bone.

To summarize, in the study group (n = 607), 531 implants (87.5%) received exclusively autologous bone for augmentation, whereas for 67 implants (12.5%) bone replacement material was mixed with autologous bone in such a way that the cranial 4 mm of the implant neck received pure autologous bone.

3.4.5. Bone grafting complications

Complications from the harvest site occurred in 6 patients (2.2%) (Table 6) and at the grafting site in 3 patients (1.1%) (Table 7).

Harvesting bone from the immediate vicinity (local bone graft) did not lead to any complications. After mandibular bone grafting, five minor complications were seen but without permanent loss of sensation or similar complications. According the Clavien-Dindo classification, the worst grade (II) was an acute infection, which was treated with antibiotics. Also, harvesting bone from the hip was not accompanied by important complications; that is, no infection, no hemorrhage, and no fracture of the iliac crest occurred. One of the 15 patients used a crutch (Clavien-Dindo grade I) in the post-operative period, whereas 14 patients did not.

All but two sinus floor augmentations (n = 106) healed well: twice a postsurgical infection of the maxillary sinus occurred and was successfully treated with antibiotics. Importantly, all planned implants could be inserted (n = 182). No other complications occurred, that is, there was no intraoperative or post-operative hemorrhage, no graft resorption, and no loss of the graft. One

Table 4
Study Group: patients and implants in combination with autologous bone graft.

Type of bone graft	Patients (n)	Patients (%)	Implants (n)	Implants (%)
local bone graft	218	79.5	429	70.7
mandibular bone block graft	41	15.0	97	16.0
hip bone graft	15	5.5	81	13.3
total	274	100	607	100

Table 5
Sinus floor augmentations (SFA).

SFA (n)	Autologous bone (%)	Bone substitute (cc)	Implants (n)
75	100	0	134
17	75	0.25	25
14	50	0.5	23
Sum 106			**Sum 182**

implant was removed after 7 years due to severe peri-implantitis. Thus, 181 implants (99.5%) were in function.

3.5. Peri-implant mucositis and peri-implantitis

The deepest probing depth of all 846 implants are shown in Table 8. In all, 64 implants (7.6%) in 39 patients (10.2%) showed signs of peri-implant mucositis with varying probing depths, but all with BoP/suppuration. No implant in this group had insufficient access for cleaning. However, all patients with peri-implant mucositis were not cleaning well. In addition, around one implant, a surplus of luting cement was found.

A further 14 patients (3.6%) with 17 implants (2.0%) were affected by peri-implantitis, three of those were lost (Table 9). In the control group, five implants (2.09%) were affected by peri-implantitis, whereas 12 implants (1.98%) from the study group were affected by peri-implantitis.

Mean time in function for implants without signs of peri-implantitis was 79.1 months (SD = 49.8) in the control group and in the study group 71.0 months (SD = 46.8) in the study group.

Mean time in function for implants with peri-implantitis was 103.8 months (SD = 49.0) in the control group and 108.4 months (SD = 39.6) in the study group.

The difference in means of the control group and study groups regarding peri-implantitis was not statistically significant ($p = 0.8405$).

Kaplan-Meier analysis showed that the 95% confidence interval could not be calculated for time to detection of occurrence of peri-implantitis, because the number of events was too small (14 of 384 patients, 370 patients were censored; and 17 of 846 implants, 829 implants were censored).

Table 9 shows that 11 (64.7%) of the 17 implants affected by peri-implantitis occurred in nine patients with a history of periodontal disease; this was the most important risk factor for the development of peri-implantitis, and it was present in the control group (two patients) as well as in the study group (7 patients). Oral hygiene was insufficient for eight implants in five patients, one of which could not clean well three implants because of impaired access (patient AD[123]). Three patients with four implants affected had not undergone dental check-ups for up to 7 years, and three of these patients had re-started smoking. No patient affected by peri-implantitis had diabetes or was on antiresorptive medication. Two further obvious reasons for the development of peri-implantitis were seen: one patient had a loose crown on a lower molar implant without having access to a specialist dentist abroad for eight months. The other patients implant was overloaded after the patient lost two neighboring teeth without replacing these prosthetically. The onset of peri-implantitis occurred in all four observation periods (Table 3). Although, during the first 5 years, very little bone loss due to peri-implantitis occurred, a peak (4.4%) was seen in the present study between 7 and 10 years of follow-up. In the group with implants longer than 10 years in function, the prevalence of peri-implantitis was 2.2%. No differences for the occurrence of peri-implantitis was found with regard to the type of autologous bone graft, sinus floor augmentation surgery, or distribution and grafting material, or whether implants were inserted during or after sinus floor augmentation in a second stage.

Among the 17 implants affected by peri-implantitis, no excess luting cement was found. All implants were Straumann implants, and eight implants were bone-level implants, of which five were placed in the posterior region (four maxillary implants, one mandibular implant). One affected patient had three bone-level implants in the maxillary premolar region and three tissue-level implants in the molar region. All three bone-level implants were badly affected by peri-implantits, whereas the tissue level implants remained unaffected.

3.6. Implant failure and success rates

Loss of implants due to peri-implantitis occurred in three patients with one implant failure in each case. Two implants showed

Table 6
Complications at harvest site.

Harvest site	n	Complication	Clavien-Dindo classification (grade)	Incidents (n)
Mandibular bone graft	41	Hemorrhage	IIIa	0
		Acute infection, antibiotics	II	1
		Acute infection/abscess, surgery	IIIa	0
		Chronic infection	IIIa	0
		Permanent loss of sensation	IIIb	0
		Temporary loss of sensation	I	4
		Chronic pain/paraesthesia	II	0
		Scaring, impairing the cleaning of molar teeth	I	1
Hip bone graft	15	Hemorrhage	IIIb	0
		Fracture of anterior Iliac spine	IIIb	0
		Infection	II	0
		Pain, needing crutches for five days	I	1

Table 7
Complications at grafting site.

Grafting site	n	Complication	Clavien-Dindo classification (grade)	Incidents (n)
Widening alveolar process	429	Graft rejection	III	0
		Acute infection	II	0
		Chronic infection	IIIa	0
Augmentation of floor of sinus	106	Mucosal perforation needing repair with membrane in same operation	IIIa	1
		Graft rejection	III	0
		Acute sinusitis	II	2
		Chronic sinusitis	IIIb	0
		Insufficient grafting	IIIa	0
		Resorption with loss of implant	III	0

Table 8
PPD and BoP.

PPD (mm)	n	BOP (n)
1	96	0
2	381	0
3	221	5
4	80	31
5	24	21
6	2	2
7	3	3
8	1	1
9	1	1

rapid worsening of the situation within weeks of detection of peri-implantitis. No hygienic measures could prevent the loss, which occurred within weeks, and the implants were removed either by the patient or by the dentist by using only their fingers. In one case of peri-implantitis, the infection was deemed too advanced to try any other treatment than removing the implant. Thus, three implants out of 846 failed due to peri-implantitis (0.35%).

Four implants failed for reasons other than peri-implantitis (Table 10): one implant failed to osseo-integrate (early failure), two implants fractured due to overload, and one implant became mobile for unknown reasons without signs of infection and without crestal bone loss but possibly also due to overload. Adding these four implant failures to the three failures due to peri-implantitis resulted in an overall success rate of 99.17% in 846 implants.

4. Discussion

The generally high prevalence of peri-implantitis reported (Berglundh et al., 2018; Heitz-Mayfield et al., 2018a; Jung et al., 2018; Schwarz et al., 2018; Karlsson et al., 2019; Salvi et al., 2019), the call to receive studies from private practice (Zitzmann and Berglundh, 2008), and the lack of reports from maxillofacial surgery departments in this regard triggered the present retrospective study. The study investigates the outcome of implants placed in private practice in Oxford, UK, by one maxillofacial surgeon working in collaboration with general dentists with specialized training in implant prosthetics. The surgeon had gained 10 years' experience with implant surgery elsewhere before coming to Oxford.

Great effort was made to avoid investigating a convenient sample. Having investigated 91.2% of the entire cohort of patients, this task was certainly achieved. It has been helped by the fact that the level of general education in the Oxford region is high, and thus the acceptance for such a study was high. Only three contacted patients could not take part. Several other patient-centered observations may help to explain the reported low prevalence of peri-implantitis: by going for yearly check-ups to the dentists and hygienists (82.5% of patients), this cohort has a generally very high compliance rate. It is further underlined by the fact that only 25 patients (6.5%) had preoperatively a history of periodontal disease. This has become a focus for research into the susceptibility to peri-implantitis (Vagia et al., 2021). Also, the rigid patient selection before implant treatment, for example, the refusal of smokers, who have a known higher risk of complications (Casado et al., 2019), is

Table 9
Characteristics of 14 patients with 17 implants affected by peri-implantitis.

Patient	Pristine bone (control)	Grafted bone (study)	History of periodontal disease	Oral hygiene insufficient	No dental follow-up (years)	Relapse of smoking	Implant position	Loaded for (months)	Implant type	additional obvious reason
PJ	X		x	x			37	70	TL	Very loose crown for eight months
NS	X		x				47	53	BL	
ED	X						25	113	TL	
BP	X						11	67	BL	
BJ	X						22	117	TL	
AH		x	x				13	118	TL	overloading
BG		x		x	4	x	22	67	BL	
LB [1]		x		x[1]	7	x	11	134	BL	
LB [2]		x		x[2]	7	x	23	134	TL	
DM		x	x				22	102	TL	
AD [1]		x	x[1]	(x)			24	91	BL	cleaning access impaired
AD [2]		x	x[2]	(x)			25	91	BL	dto
AD [3]		x	x[3]	(x)			14	91	BL	dto
FC		x	x				22	24	BL	
GI		x	x				27	81	TL	
KG		x	x	x	6	x	22	122	TL	
RJ		x	x				14	68	TL	

TL = Tissue Level.
BL = Bone Level.

Table 10
Implant failures.

Reason	n
Early failure, i.e. no osseointegration	1
Peri-implantitis	3
Overloading (fracture)	2
Unknown	1
Sum	**7**

an important reason for the reported low prevalence of peri-implant disease: peri-implant mucositis was low in patients (10.2%) and in implants (7.6%) as well as was peri-implantitis (3.6% and 2.0% respectively) in the entire cohort. The same low prevalence of peri-implantitis was observed in the control group as in the study group, with no statistically significant difference.

For 607 implants (71.7%), bone augmentation was necessary. This high proportion can be explained by the fact that the patients underwent surgery in a maxillofacial surgery practice and often were referred in more demanding situations. It is similarly high to a recent report from a university surgical specialty clinic (Ducommun et al., 2019).

Using autologous bone for grafting has been advocated for a long time. Short-term studies have shown success rates similar to those of the present one (Chiapasco et al., 2008; Felice et al., 2014; Corbella et al., 2015). This study, however, gives medium (7–10 years loading) and long-term results (more than 10 years loading). Most scientific reports by maxillofacial surgeons are concerned with other aspects of the treatment. However, when maxillofacial surgeons report on the aspect of peri-implantatis and complications from autologous bone grafting procedures, results are often better than those of dental colleagues (Chiapasco et al., 2008, 2020; Merli et al., 2021), as in the present study. Also, the reported low prevalence of peri-implantitis in both the control and study groups in the present study indicates that augmentation with autologous bone does lead to a decreased risk. The use of bone replacement materials was restricted to fill undercuts, to smoothen the edges of bone grafts, and to gain volume in sinus floor augmentations. Knowing that bone replacement materials are, by definition, dead tissue at least at the time of placement, they were completely avoided around the necks of implants.

Harvesting autologous bone obviously carries the risk of complications from the harvest site. Regarding lesions of the inferior alveolar nerve after mandibular bone block grafts, only three patients reported transient paraesthesia for 3 months, and no patient reported permanent loss of sensation. Together with one infection and one unfavorable scar after MBBG, the complication rate at this harvest site amounts to 12.2%. This is similar to the results of other maxillofacial surgeons (Chiapasco et al., 2008, 2020), whereas dental units reported a higher complication rate at intraoral donor sites of up to 31.6% (Al-Nawas and Schiegnitz, 2014; Thoma et al., 2019). Also, harvesting bone from the hip carries a certain risk. Although the surgical outcome of the present study did not reveal any important complication, it was the increased costs that prevent hip bone from being used more often.

For 91 patients, 106 sinus floor augmentation procedures in lateral window technique were carried out. None failed, although two infections occurred and were treated successfully with antibiotics. Infected autologous bone obviously heals better than infected bone replacement material, especially allografts, which may not heal at all, thereby preventing the induction of bone growth. Only one implant among 182 implants was lost 7.5 years after loading due to peri-implantitis. Thus, 181 implants (99.5%) are in function. Also, no early failure of an implant was seen after sinus floor augmentation. This is in sharp contrast to studies in which bone replacement materials were used. A recent study reported up to 5% of early failures (Kraus et al., 2020). Better outcome was reported if residual alveolar bone height allowed for implant placement at the time of sinus floor augmentation (Thoma et al., 2018). The present study did not reveal differences between one- or two-stage surgery. Implant survival probability is better when experienced providers are likely to temper known risk factors in clinical decisions and when expert surgeons perform the intervention (Merli et al., 2021; Schoenbaum et al., 2021). Individual surgeons have an important impact on the risk of implant failure, with early implant failure being reported in a large study as high as 4.4% of patients and 1.4% of implants (Derks et al., 2015; Jemt, 2018). This study though revealed only one early implant failure (0.12%). Also, the fact that only one implant was found with a surplus of luting cement (which was described as a cause for peri-implant disease (Staubli et al., 2017) and that very little critique was raised by the investigators in respect to the prosthetic rehabilitation indicates that also the work of the dentists involved was of high quality.

Two-thirds of the present patients who were found to have peri-implantitis had previously had periodontal disease (nine of 14 patients). Recently, it has been shown that this is a higher-risk group (Kumar, 2019). Even under regular supportive post-implant treatment, it remains a negative risk indicator (Lin et al., 2020). It has also recently been suggested that it is also the one factor unable to be modified when performing an implant disease risk assessment (Heitz-Mayfield et al., 2020).

This study is limited by a somewhat short mean time in function of 79 months in the control group and 71 months in the study group. However, 342 implants were loaded for 7 years or longer, and 159 implants were in function for 10 years or longer. Although the study compares the use of autologous bone for augmentation to implant insertion without grafting, it falls short of the need for long-term follow-up studies comparing autologous bone grafting to grafting with bone substitutes (Moraschini et al., 2015; Thoma et al., 2019).

Despite previously reported controversial data for long-term success of bone augmentation procedures (Visser et al., 2016; Chappuis et al., 2017) and no statistically significant differences in a systematic review and meta-analysis (Salvi et al., 2018), this study provides evidence that implants inserted into pristine bone have the same low prevalence of peri-implantitis as implants inserted into autologous bone grafts.

5. Conclusions

Within the limitations of the study it seems that the use of autologous bone still is a relevant option when performing augmentation procedures because of the low prevalence of peri-implantitis.

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Author contributions

P.F.C. performed all surgical procedures, conceived the idea, and submitted the study design to the ethical committee; M.L. carried out parts of the prosthetic work; J.T.L. and F.C. helped with the study design; J.T.L., M.B., and FC collected the data; P.F.C., M.B., F.C., and J.T.L. analyzed the data; P.F.C. led the writing; J.T.L. and F.C. undertaking critical revision of the article.

Prior presentation

Parts of this study were presented at meetings of the European Association of Osseointegration (EAO) and accepted for a Doctorate (MB) at the University of Zurich, Switzerland.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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