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Dental implants placed in resorbed alveolar ridges reconstructed with iliac crest autogenous onlay grafts: A 26-year median follow-up retrospective study

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ABSTRACT

Purpose: To evaluate the long-term outcome of dental implants placed with a staged procedure in resorbed alveolar ridges reconstructed with iliac crest autogenous onlay grafts.

Materials and methods: All consecutive patients treated with iliac crest onlay bone grafts and dental implants were retrospectively evaluated. During the appointment, clinical and radiological examinations were conducted to assess implant survival. A survived implant was defined as an implant still stable and in function at the follow-up visit. Implant survival was estimated at the implant level using Kaplan-Meier analyses. The cumulative survival rate was estimated using a life-table analysis. Subgroup analyses were performed for age, position, and type of retention using the log-rank test. A p-value of <0.05 was considered statistically significant.

Results: The cohort consisted of 21 female subjects receiving a total of 140 rough-surface titanium implants. Of them, 128 survived and 12 failed, yielding a cumulative survival rate of 91.1% over a median survival time of 312 months. Implants supporting cement-retained prostheses exhibited lower survival rate compared to screw-retained restorations ($p = 0.001$).

Conclusion: Implants placed in bone augmented with iliac crest onlay grafts showed high long-term survival rates. Cement-retained restorations were more prone to develop implant failures.

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1. Introduction

Current trends in implant dentistry advocate the concept of prosthetically guided bone regeneration (Chiapasco and Casentini, 2018). The goal is to place implants according to aesthetic and functional principles as primary determinants for successful rehabilitations. Thus, bone augmentation procedures become essential in demanding anatomical situations of inadequate bone quality and quantity to restore an ideal amount of supporting bone. This allows restoration-driven implant insertion, with the rationale

to follow the prosthetic needs in order to achieve the anticipated treatment outcome (Garber and Belsler, 1995).

Several bone augmentation techniques have been developed to re-establish the ideal contour of the alveolar ridge for implant placement purposes. Most of the techniques including autogenous onlay bone grafts have shown irrelevant differences in terms of implant survivals in the edentulous maxilla (Aghaloo et al., 2016) and mandible (de Groot et al., 2018). At the same time, there is certain evidence suggesting that, irrespective of the technique, autogenous bone can still be considered the gold standard material in alveolar ridge augmentation prior to oral implantation (Sakkas et al., 2017). These findings taken together may explain the successful results obtained with iliac crest autogenous onlay grafts used in pre-prosthetic surgery to augment the missing bone (Maiorana and Santoro, 2002; Sjostrom et al., 2007; Nystrom et al., 2009; Boven et al., 2014; Fretwurst et al., 2015).

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Morphologically, the superior-anterior rim of the iliac crest is suitable for large volume reconstructions. Additionally, the rich, dense, cancellous bone enclosed by thinner compact bone, could promote implant osseointegration (Sonmez et al., 2013). Moreover, anterior iliac crest showed low long-term donor site morbidity, resulting in high patient satisfaction (Putters et al., 2018). On the other hand, numerous complications related to the harvesting procedure have been encountered, including hemorrhage, hematoma, altered sensation in the distribution of the lateral femoral cutaneous nerve, pain, wound dehiscence, wound infection, abdominal hernia, fracture, gait disturbance, and impaired mobility (Scheerlinck et al., 2013). Furthermore, unavoidable and slowly progressive bone resorption of iliac crest autogenous onlay grafts has been documented as major side effect over time (Vermeeren et al., 1996; van der Meij et al., 2005; Sbordone et al., 2012). Despite this inevitable bone remodeling, however, complete integration and embedding of implants installed in iliac crest autogenous block grafts have been observed radiographically (Dasmah et al., 2012). Accordingly, extensive peri-implant bone loss occurring within the first year has been found, while similar bone level changes compared to implants inserted in non-augmented regions have been reported thereafter (Fretwurst et al., 2015).

Long-term studies evaluating the survival rates of dental implants placed in sites augmented with iliac crest autogenous onlay grafts are lacking. Considering implants followed retrospectively for periods longer than 10 years, survival rates ranged from 90% (Nystrom et al., 2009) to 100% (Moses et al., 2007). However, to the best of our knowledge, no studies are currently available reporting on survival analysis performed with more than 20 years of follow-up.

In view of the aforesaid, the primary aim of the present retrospective cohort study was to evaluate the survival rate of dental implants placed in resorbed alveolar ridges reconstructed with iliac crest autogenous onlay grafts. The secondary endpoint was to analyze the survival rate in relation to specific variables, namely the age of the patients, the position of the implants, the type of uncovering procedure, and the type of prosthesis.

2. Materials and methods

2.1. Study design and patient selection

The present study was conducted as a monocentric observational retrospective cohort evaluation performed in a university setting. This study was performed within the guidelines of the World Medical Association Declaration of Helsinki of 1975 for biomedical research involving human subjects, as revised in 2013. This study was reported in accordance with the STROBE guidelines for reporting observational studies. The present study was carried out between January and June 2018. During this interval, all consecutive patients treated between 1993 and 2001 with iliac crest autogenous onlay bone grafts and dental implants in atrophic jaws were invited with telephone calls to attend the authors' Department for a recall visit. All participants were informed of the aims and methods of the study and provided written consent to participate.

Patients of both genders were eligible for inclusion in this study if they had been treated with dental implants placed with a staged procedure in bone augmented with autogenous onlay block grafts harvested from the iliac crest. Implants placed in sites treated with particulated iliac crest grafts or implants placed in bone augmented with interpositional inlay block grafts were excluded. Anatomically, patients had to present with partial or total maxillary or mandibular atrophy classified as Class IV to VI according to Cawood and Howell classification of alveolar bone resorption (Cawood and

Howell, 1988) (Fig. 1). None of the patients had any systemic diseases, nor were they taking any medication on a daily basis at the time of the surgical intervention. Patients with a history of radiotherapy to the head and neck region, or who had been diagnosed with bone diseases, immunosuppressive diseases, or were smokers (≥ 10 cigarettes/day), were excluded.

2.2. Treatment phases

All surgical procedures were conducted by the same surgeon (CM). The reconstructive surgery was performed under general anesthesia according to a standardized protocol (Maiorana and Santoro, 2002). In brief, intraoral low vestibular incisions or crestal incision associated with vertical releasing incisions were performed to reflect a mucoperiosteal flap and expose the residual bone. Veneers or saddle-shaped corticocancellous bone blocks harvested from the antero-superior iliac crest were molded and contoured to obtain the ideal shape to replace the missing bone. Following cortical perforations of the recipient bed, appositional onlay blocks were fixed by means of 1.6-mm-diameter osteosynthesis screws (KLS Martin, Tuttlingen, Germany). Morcellized bone chips maintained in situ by resorbable collagen membranes were grafted to fill the gaps between the onlays and the alveolar bone. Mucoperiosteal flaps were finally released through periosteal incisions and closure was obtained with horizontal mattresses and single stitches (Fig. 2A and B). During the first 2 months from preprosthetic surgery, patients were not allowed to wear removable prostheses. Afterwards, pre-existing or new partial or complete removable dentures were relined with a resilient material (Soft Liner; GC Corporation, Tokyo, Japan), relieved from the grafted area, and supplied to the patients. During the subsequent recall visits up to the delivery of the temporary implant-supported prosthesis, dentures were relined when needed to avoid excessive compression to the augmented bone.

After a healing period of 4–6 months, implants were placed with a submerged approach on an outpatient basis according to the manufacturers' instructions (Fig. 3A–C). A surgical guide based on the prosthetic wax-up was used to place implants in the ideal prosthetically guided position. Different implant diameters and lengths were used to best fit the augmented alveolar ridge.

Uncovering of the implants to connect the healing abutments was carried out 6 months after the implant insertion. After soft tissues maturation, impressions were taken with custom impression trays to begin with the prosthetic phases. Temporary implant-supported acrylic resin prostheses were connected to the implants for initial load and soft tissues conditioning. After 6 months, definitive implant-supported screw- or cemented-retained metal-ceramic prostheses were delivered to the patients and an orthopantomograph was performed (Fig. 4A and B).

All patients were on a recall schedule of at least once a year after treatment by the same surgical team.

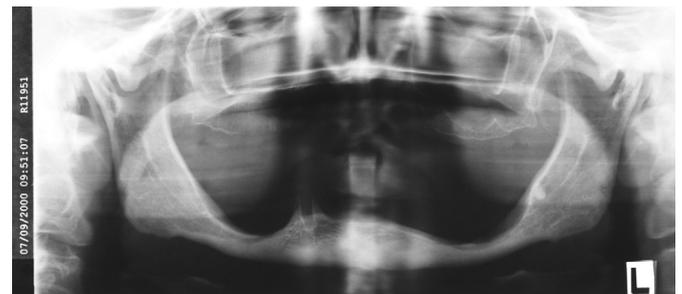


Fig. 1. Baseline orthopantomograph of a fully edentulous patient performed in September 2000.

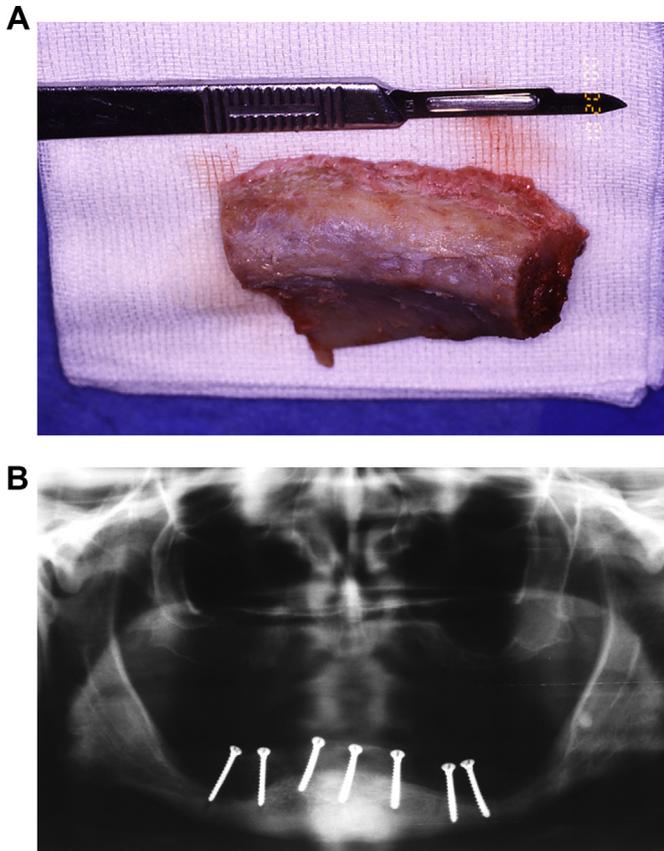


Fig. 2. Pre-prosthetic surgery performed in October 2000. A) Clinical view of the iliac crest autogenous block graft harvested during the reconstructive surgery; B) Post-operative orthopantomograph showing the iliac crest onlay grafts stabilized by osteosynthesis screws.

2.3. Data collection

The medical records of all eligible patients were assessed. Patient characteristics such as age and sex, date of preprosthetic surgery, date of implant placement, implant position, implant

brand, type of surface, date of implant loading, type of retention, occurrence of peri-implantitis and technical complications, date of the last follow-up visit, and date of implant loss were recorded. With respect to the diagnosis of peri-implant disease in the absence of initial radiographs and probing depths, peri-implantitis was diagnosed in case of radiographic evidence of bone level ≥ 3 mm and/or probing depths ≥ 6 mm in conjunction with profuse bleeding at the time of the last follow-up visit (Renvert et al., 2018).

Survived implant was defined as an implant still clinically stable and in function at the follow-up visit. An implant was considered lost once it was removed permanently from the mouth. Accordingly, implant survival was defined as the period between implant placement and the last follow-up or loss of the implant. During the appointment, clinical stability was assessed by mechanical testing with a hand instrument. In case of implants supporting a clinically stable bridge, the supra-construction was removed to check for individual stability of each implant.

Patients were asked to provide the latest orthopantomograph to support the clinical examination. If the radiological exam was performed ≥ 1 year before the appointment, a new orthopantomograph was requested (Fig. 5A–C). Replaced implants if any, were excluded for further survival analyses.

2.4. Statistical analysis

A database was created using database software (Excel, Microsoft Corp., Redmond, WA, USA) allowing calculations to be performed automatically. All data were imported into statistical analysis software (IBM SPSS Statistics, Version 24.0, IBM Corp., Armonk, NY, USA) for further statistical analysis. Descriptive statistics were used to explore the study variables, including estimated mean (EM) \pm standard error (SE), and 95% confidence intervals (95% CI). Implant survival was estimated at the implant level using Kaplan-Meier analyses. The cumulative survival rate was estimated using a life-table analysis. Subgroup analyses were performed for age (≤ 53 versus >53 years of age, being 53 the median value), position (maxilla versus mandible), and type of retention (screw-retained versus cement-retained). The survival of subgroups was compared using the log-rank test. A p-value of <0.05 was considered statistically significant.

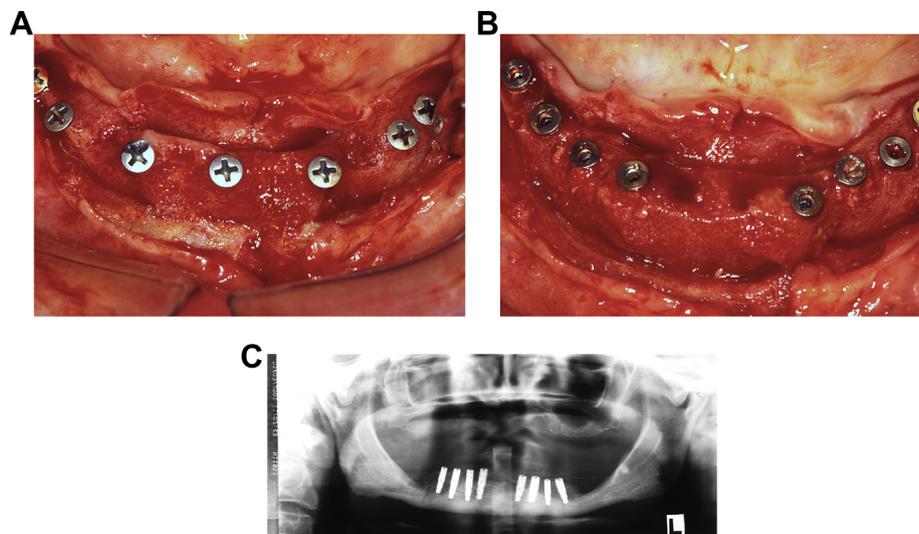


Fig. 3. Implant placement performed in March 2001. A) Intraoral view of remodeled iliac crest autogenous onlay grafts clinically osseointegrated within the recipient mandibular site; B) Placement of 8 rough surfaced titanium implants in well vascularized augmented bone; C) Post-operative orthopantomograph showing the implants inserted in integrated iliac crest autografts.

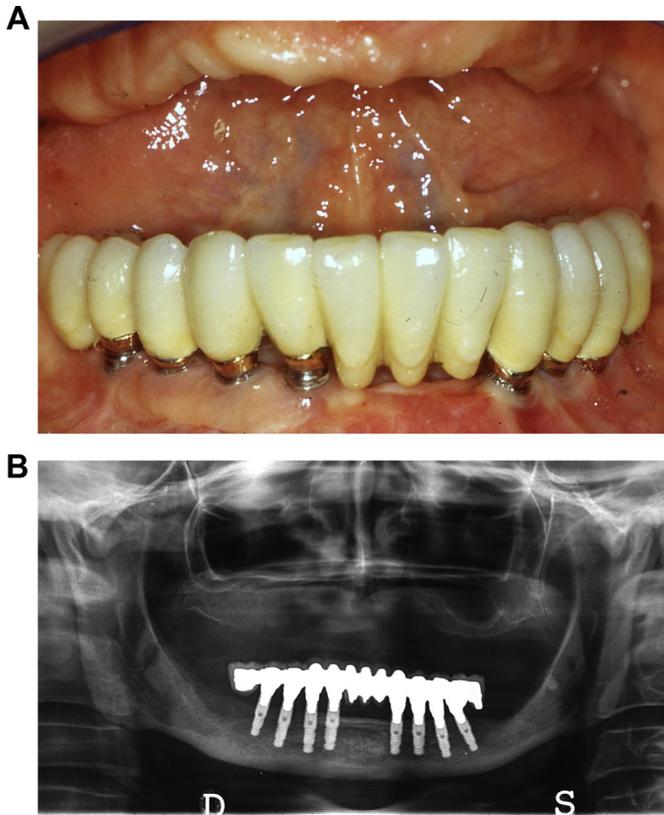


Fig. 4. Delivery of the final restoration. A) Definitive implant-supported prosthesis in position; B) Orthopantomograph performed at the delivery of the definitive prosthesis.

3. Results

Between 1993 and 2001, a total of 24 patients characterized by atrophic alveolar ridges were rehabilitated with dental implants placed with a staged procedure in bone augmented with autogenous onlay block grafts harvested from the iliac crest. The medical records of 3 patients were incomplete, and it was not possible to retrieve the necessary information. The remaining 21 patients agreed to participate in the present study (Table 1). All were female subjects with a mean age at the time of preprosthetic surgery of 51.02 ± 12.81 (range: 28–71 years of age). A total of 140 rough-surface titanium implants were placed. Of them, 128 survived and 12 failed, yielding a cumulative survival rate of 91.1% over a median survival time of 312 months ($EM \pm SE = 287.30 \pm 7.09$ months; 95% CI = 273.4–301.2 months) (Table 2 and Fig. 6). It is noteworthy that one patient (#8) lost all of the implants placed in the mandible. In particular, five sandblasted acid-etched implants were loaded after 6 months from the insertion and were lost after roughly 2 years of function. The patient had a non-contributory medical history. Interestingly, this was the only case in which the patient refused a temporary prosthesis and decided to be rehabilitated directly with a definitive prosthesis. The final restoration consisted of an implant-supported metal-ceramic bridge cemented to the implants. After the delivery of the definitive prosthesis, the patient moved to another city and could not be followed up on a regular basis. From the medical records, it has been hypothesized that the absence of a progressive load together with a possible excessive occlusal overload exacerbated by inflamed peri-implant tissues might have led to early failure of the implants.

A log rank test was run to determine if there were differences in the survival distribution for potential confounding factors.

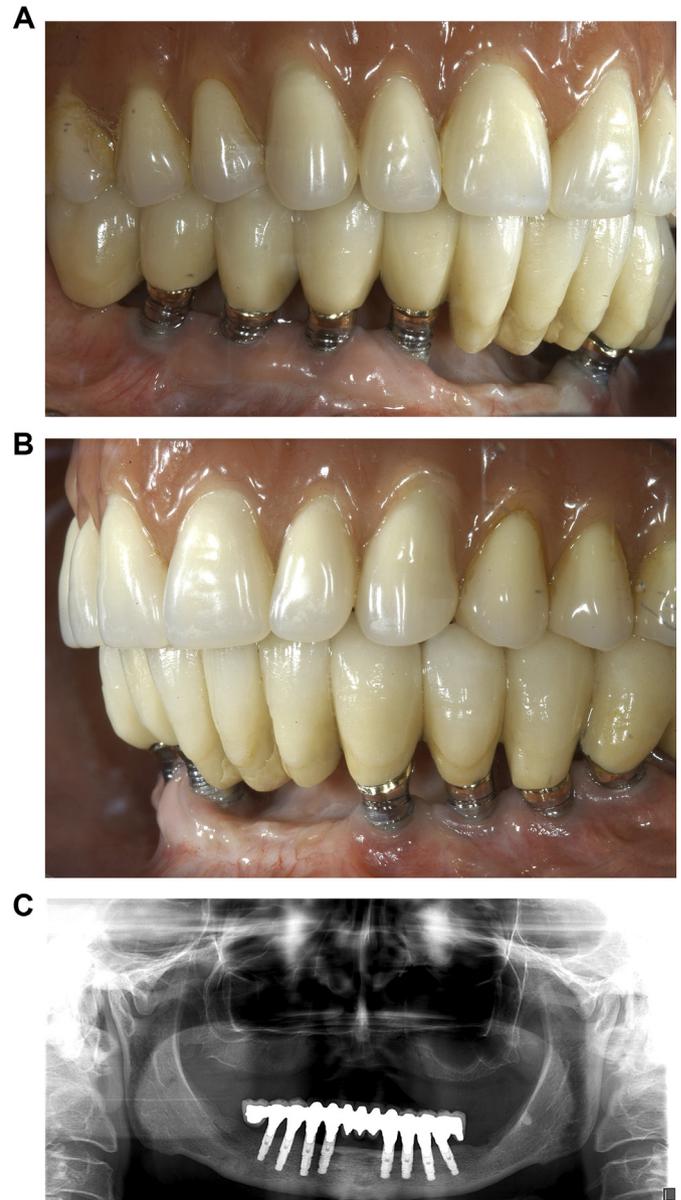


Fig. 5. A, B) Left and right intraoral views of the definitive restoration supported by 8 implants still in function at the 17-year follow-up recall; C) 17-year follow-up orthopantomograph showing healthy implants and stable peri-implant marginal bone levels.

Considering the age of the patients, 80 implants were placed in subjects aged ≤ 53 years of age, while 60 implants were inserted in older subjects. Seven implants failed in the first group whereas 8 implants failed in the second group. Cumulative survival rates of $91.1 \pm 3.2\%$ and $91.5 \pm 3.6\%$ were found for patients aged ≤ 53 and >53 years of age respectively (Fig. 7). The survival distributions for the two age groups were not statistically significantly different ($\chi^2(1) = 0.022$, $p = 0.881$).

With respect to the surgical site, 79 implants were placed in the maxilla, while 61 implants were inserted in the mandible. Seven implants failed in the first group whereas 5 implants failed in the second group. Cumulative survival rates of $91 \pm 3.3\%$ and $91.6 \pm 3.6\%$ were found for implants placed in the maxilla and mandible, respectively (Fig. 8). The survival distributions for the two anatomical regions were not statistically significantly different ($\chi^2(1) = 0.041$, $p = 0.839$).

Table 1
Demographic data and clinical features of patients and implants.

Patient ID	Sex	Age (years)	Date of implant insertion	Surface	Surgical site	Uncovering procedure	Type of retention	Number of implants	Number of failures	Survived implants (%)
1	F	49	March-01	Rough	Mandible	Complex	Screw-retained	8	0	100,00%
2	F	28	January-97	Rough	Maxilla	Simple	Cement-retained	5	0	100,00%
3	F	41	October-03	Rough	Maxilla	Complex	Cement-retained	8	0	100,00%
4	F	40	November-02	Rough	Maxilla	Complex	Cement-retained	4	0	100,00%
5	F	48	May-05	Rough	Maxilla	Complex	Cement-retained	3	0	100,00%
6	F	42	March-99	Rough	Maxilla	Complex	Cement-retained	12	3	75,00%
7	F	62	October-00	Rough	Maxilla	Simple	Screw-retained	8	0	100,00%
8	F	68	January-06	Rough	Mandible	Simple	Cement-retained	5	5	0,00%
9	F	58	October-04	Rough	Mandible	Simple	Screw-retained	4	0	100,00%
10	F	57	September-03	Rough	Maxilla	Simple	Screw-retained	8	0	100,00%
11	F	48	October-00	Rough	Mandible	Complex	Cement-retained	6	0	100,00%
12	F	35	December-91	Rough	Maxilla	Simple	Screw-retained	8	0	100,00%
13	F	63	January-99	Rough	Mandible	Simple	Screw-retained	5	0	100,00%
14	F	33	October-02	Rough	Mandible	Simple	Screw-retained	5	0	100,00%
15	F	28	June-00	Rough	Maxilla	Simple	Cement-retained	7	1	85,70%
16	F	67	March-01	Rough	Mandible/Maxilla	Simple	Screw-retained	14	0	100,00%
17	F	60	March-95	Rough	Mandible	Simple	Screw-retained	6	0	100,00%
18	F	53	April-00	Rough	Maxilla	Simple	Cement-retained	8	3	62,50%
19	F	71	January-98	Rough	Mandible	Simple	Screw-retained	6	0	100,00%
20	F	62	March-02	Rough	Mandible	Simple	Screw-retained	4	0	100,00%
21	F	53	November-93	Rough	Mandible	Simple	Cement-retained	6	0	100,00%

Finally, 76 implants were rehabilitated with screw-retained prostheses, while 60 implants supported cement-retained restorations. Four implants were lost before being loaded and were therefore excluded from the survival analysis. No implants failed in the screw-retained group, while 8 implants failed in the cement-retained group. Thus, cumulative survival rates of 100% and $85.6 \pm 4.7\%$ were respectively found (Fig. 9). The survival distributions for the two retention types were statistically significantly different ($\chi^2(1) = 11.385$, $p = 0.001$).

Table 2
Life-table analysis showing cumulative survival rates of implants.

Interval	Implants at start of interval	Drop-out implants	Implant failures	Survival proportion on interval	Cumulative survival proportion at the end of interval
0–12 months	140	0	4	0,97	0,97
1–2 years	136	0	1	0,99	0,96
2–3 years	135	10	5	0,96	0,93
3–4 years	120	0	1	0,99	0,92
4–5 years	119	0	1	0,99	0,91
5–6 years	118	16	0	1	0,91
6–7 years	102	0	0	1	0,91
7–8 years	102	5	0	1	0,91
8–9 years	97	0	0	1	0,91
9–10 years	97	0	0	1	0,91
10–11 years	97	0	0	1	0,91
11–12 years	97	0	0	1	0,91
12–13 years	97	12	0	1	0,91
13–14 years	85	7	0	1	0,91
14–15 years	78	6	0	1	0,91
15–16 years	72	4	0	1	0,91
16–17 years	68	16	0	1	0,91
17–18 years	52	27	0	1	0,91
18–19 years	25	0	0	1	0,91
19–20 years	25	6	0	1	0,91
20–21 years	19	5	0	1	0,91
21–22 years	14	0	0	1	0,91
22–23 years	14	0	0	1	0,91
23–24 years	14	0	0	1	0,91
24–25 years	14	6	0	1	0,91
25–26 years	8	1	0	1	0,91
26–27 years	7	7	0	1	0,91

Overall, three patients showed clinical and radiological signs of peri-implantitis at the latest follow-up visit. In two patients, two and three adjacent implants in the upper right jaw respectively loaded in 2004 and 2006 were affected by peri-implantitis. In one patient, two adjacent implants loaded in 1996 were diagnosed with peri-implantitis in the right mandible. None of the patients underwent implant removal during the entire follow-up period.

The technical complications detailed in the medical records and/or reported by the patients at the follow-up examinations included decementation of the prosthesis ($n = 1$ patient); fracture of the superstructure ($n = 1$ patient); replacement of the prosthesis teeth with new crowns ($n = 1$ patient); prosthetic screw loosening ($n = 2$ patients). All of these technical issues occurred in five different patients that presented no implant failures during the follow-up examinations.

4. Discussion

The present study has been developed to evaluate the long-term survival rate of dental implants placed in atrophic alveolar ridges augmented with iliac crest autogenous onlay grafts. The rationale was to provide evidence that implant rehabilitations in bone reconstructed with autogenous hip grafts might constitute a reliable treatment option on a long-term basis. Indeed, only a few studies reported on the outcome of such implant-supported rehabilitations for a period longer than 10 years. Fretwurst et al. evaluated a cohort of 32 partially or totally edentulous patients that underwent maxillary or mandibular iliac bone onlay graft augmentation (Fretwurst et al., 2015). A total of 150 implants were placed with a staged procedure. Implants were followed up for a period ranging from 12–165 months. During the observation period, 7 implants were lost, resulting in a survival rate of 95%. Similarly, Nystrom et al. retrospectively evaluated 44 edentate patients with maxillary atrophy reconstructed with iliac crest block grafts (Nystrom et al., 2009). Machined-surface implants were placed after 6 months. Of 334 implants inserted, 27 failed, yielding an estimated survival rate of 90% over a mean follow-up of 11 years. Moses et al. reported a case of severe mandibular bone atrophy treated with iliac crest onlay graft in the interforaminal region

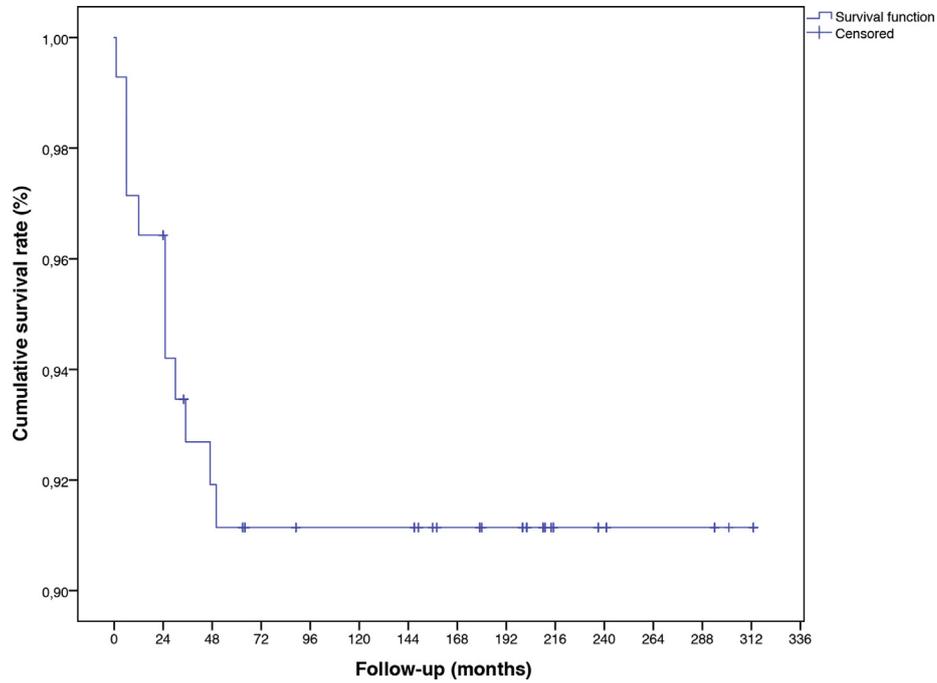


Fig. 6. Kaplan-Meier curve of the cumulative survival rate showing an estimate survival of 91.1% over a median survival time of 312 months.

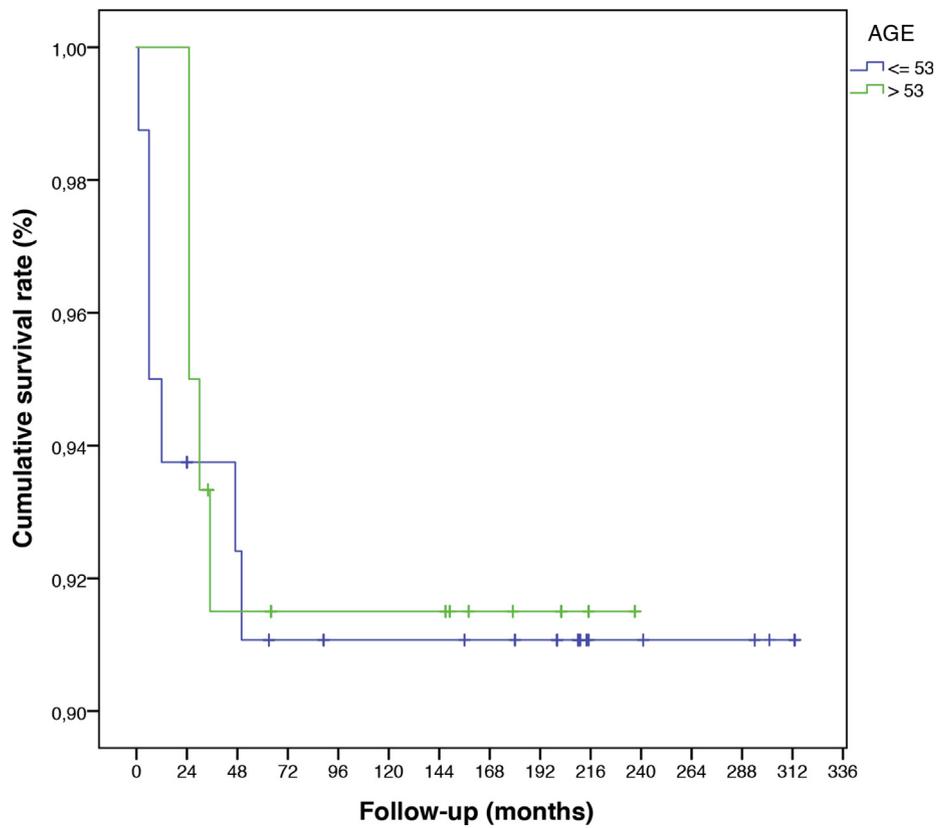


Fig. 7. Survival distributions of implants according to the patients' median age of 53 years. No statistically significant differences were detected between patients aged ≤ or >53 years.

(Moses et al., 2007). In this case, four implants were placed simultaneously with the augmentation procedure. No implants failed during the 17-year follow-up.

So far, to the best of our knowledge, no studies are currently available reporting on survival outcomes for a period longer than 20 years. Therefore, this might be the first study evaluating

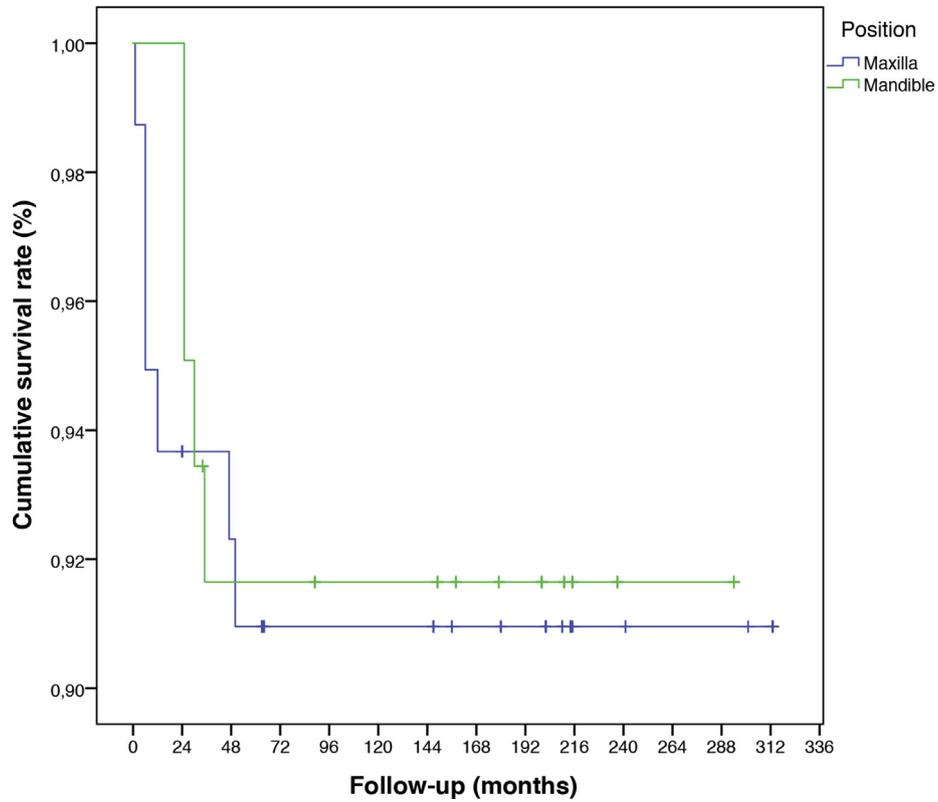


Fig. 8. Survival distributions of implants according to the surgical site. No statistically significant differences were observed between implants placed in the mandible versus implants placed in the maxilla.

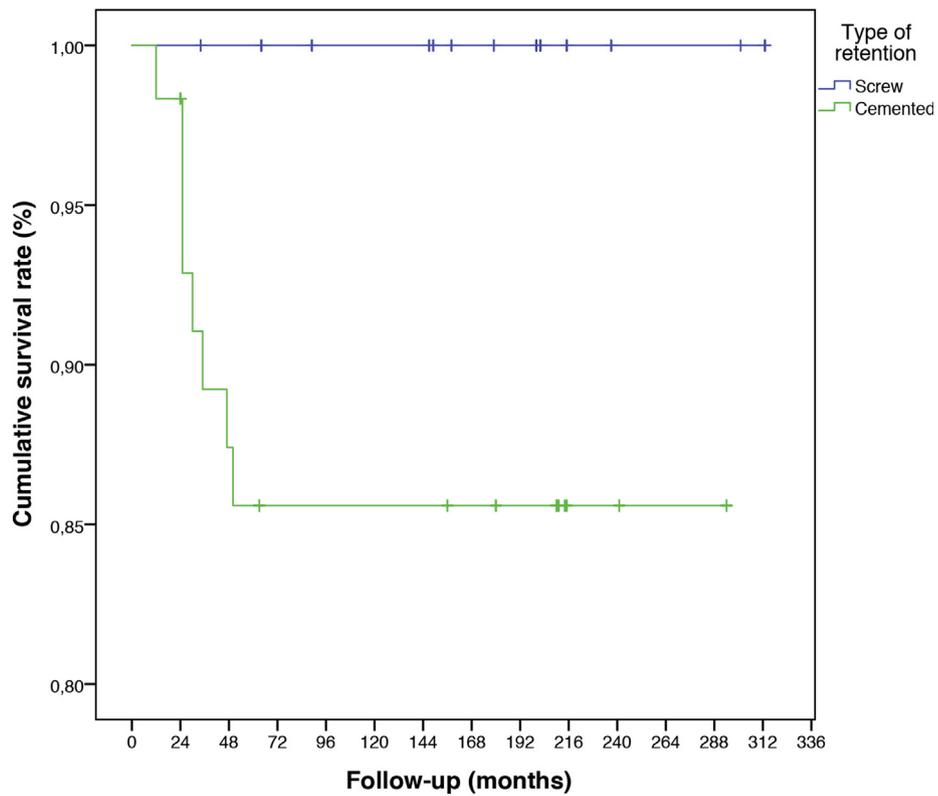


Fig. 9. Survival distributions of implants according to the type of retention. Implants supporting cement-retained restorations showed statistically lower survival rate compared to screw-retained prostheses ($p = 0.001$).

implants placed in iliac crest onlay block grafts with such a long-term follow-up. This applies to patients characterized by atrophic bone as a consequence of chronic infections, long-lasting edentulism, or previously failed bone grafts. Other causes such as trauma or resective surgery were not considered. Following this inclusion criterion, patients were enrolled if presenting with partial or total edentulism associated with a resorbed alveolar ridge classified as class IV to VI according to Cawood and Howell classification (Cawood and Howell, 1988). In the above clinical situations, rough-surface implants placed with a staged procedure in hip grafts yielded a cumulative survival rate of 91.1% with a median survival time of 312 months. The present result complies favorably with those reported in previously cited studies, strengthening the positive outcomes even after 20 years from implant insertion. At this point it is worth mentioning that Nystrom and co-workers evaluated machined implants placed in the maxilla, while Fretwurst and colleagues placed the implants after 3 months of healing, thus a direct comparison with the present study could be misleading.

Looking at studies with at least 5 years of follow-up, survival rates remained constantly over 90%. Boven et al. rehabilitated edentulous patients with iliac crest bone onlay grafts and two interforaminal implants with a delayed procedure (Boven et al., 2014). The 5-year implant survival was 98.7%. Sbordone et al. retrospectively analyzed 16 patients in whom maxillo-mandibular atrophy had been resolved by iliac crest bone blocks, dental implant insertion, and fixed prosthetic loading (Sbordone et al., 2012). No implant failure was recorded at the 6-year survey. De Bruyn et al. evaluated the overall outcome of turned titanium implants installed in iliac crest-augmented maxillary bone (De Bruyn et al., 2013). From 71 implants, only one presented with a buccal fistula and was found mobile over a mean time in function of 9 years.

It is worth noting that, in the present study, the majority of implants ($n = 10$, 83.3%) failed during the first 2–3 years from implant insertion, with 5 (41.6%) implant failures recorded within the first 12 months from implantation. In this sense, graft resorption might have played a critical role in early implant loss. Bone remodeling of iliac crest block grafts is a major side effect associated with different degrees of bone resorption. Average resorption rates of 42% and 59% after 1 year of implant positioning respectively in the anterior maxilla and in the posterior mandible have been observed (Sbordone et al., 2009b). Graft remodeling proceeded intensively during the first 2 years, slowing down during the subsequent period up to 6 years. At 6 years, this progressive and unavoidable bone remodeling resulted in resorption of almost the entire osseous graft in the maxilla and mandible, with resorption rates of 105.5% and 87% for the upper and lower arches, respectively (Sbordone et al., 2013). To reduce volumetric graft resorption, shorter durations of healing and loading might prevent undesirable resorption at grafted sites. Gultekin et al. allowed a healing period of 3 months after iliac crest bone grafting as well as an additional 3 months for implants osseointegration, resulting in a low rate of graft resorption (Gultekin et al., 2017). Tosun et al. demonstrated that implant placement after 3 months from reconstructive procedure was reliable and was associated with high survival rates and low marginal bone resorption (Tosun et al., 2018). Similarly, Raghoobar et al. performed implant insertion after 3 months from bone augmentation with iliac crest bone grafts, and loaded the implants after 2 months of healing (Raghoobar et al., 2003). The resulting survival rate was 95.6% at 1 year with minimal bone loss. These clinical observations were validated histologically by Nelson et al., who found adequate bony structure to safely place implants after a healing period of 3 months from iliac crest onlay grafting (Nelson et al., 2006). These findings taken together call for the placement of implants at an early stage during the remodeling

process. This was not performed in the present study, as implants were placed after 4–6 months and were loaded after further 6 months. One may speculate that the absence of mechanical loading during such a prolonged healing time jeopardized the physiological remodeling of the graft. Indeed, it is known that mechanical loading activate several cellular processes in osteocytes promoting bone formation. Moreover, woven bone needs mechanical loads to be replaced on basic molecular unit-based remodeling by lamellar bone. It must be noted, however, that implants failures were recorded in only 4 out of 21 patients. This probably suggests that other factors rather than merely the healing period may have triggered early implant failures. In this respect, it is worthy of mention that one patient lost all of the implants. It has been hypothesized that continuous occlusal overload on metal-ceramic crowns associated with inflamed peri-implant tissues due to difficulties in attending to follow-up recalls might have promoted early implant failures. Interestingly, a similar clinical situation of supra-occlusal contacts in the presence of inflammation significantly increased the plaque-induced bone resorption in animal models (Kozlovsky et al., 2007). It must be noted however that the same effect in human studies is poorly reported and provides little unbiased evidence to support a cause-and-effect relationship (Naert et al., 2012).

Taking into account the methodology of the studies mentioned above, certain heterogeneity can be observed. Hence, to better understand the survival curves under different clinical and prosthetic conditions, subgroup analysis of potential confounding factors has been conducted herein. Basically, no statistically significant differences in terms of cumulative implant survival rates emerged from the analysis of patients' age, and implant position. Conversely, a statistically significant difference was observed from the comparison between screw- and cement-retained restorations. This result strengthen the evidence that residual subgingival cement might contribute to the onset of peri-implant mucositis (Quaranta et al., 2017) and peri-implantitis (Schwarz et al., 2018). Additionally, in the present study patients were prosthetically rehabilitated with implant rehabilitations cemented to multiple implants. This type of prosthesis limited the access for cement detection and cleaning procedures particularly in the interdental space at the oral aspect. This clinical finding supports the fact that splinted single crowns or fixed dental prostheses are more prone to develop cement-induced peri-implant disease compared to cemented single crowns and screw-retained prostheses (Staubli et al., 2017). However, it is noteworthy that detection of cement remnants has not been recorded in the medical records of the patients included herein. Therefore, given that the association between the type of prosthesis retention and peri-implant disease remains unclear (Kotsakis et al., 2016), the comparison between screw-versus cement-retained prosthesis should be interpreted cautiously.

The present study has some limitations that should be discussed. Firstly, the sample consisted solely of female subjects. It has been observed that the mean rate of iliac crest graft resorption in female patients was significantly higher than that in male patients (Gultekin et al., 2017). This supports the findings of another retrospective study reporting significantly higher marginal bone loss in female versus male patients after 10 years around implants placed in bone augmented with iliac crest onlay grafts (Fretwurst et al., 2015). With the same follow-up, other authors found significantly higher failure distribution for implants placed in female compared to male subjects (Nystrom et al., 2009). Multivariate logistic regression analysis performed in a short-term prospective study confirmed that women were significantly associated with an increased risk for implant failure (Sjostrom et al., 2007). All these findings taken together highlight the clinical relevance of bone physiology in implant survival analyses. Although unwanted, the

effect of gender on implant survival could not be performed in the present retrospective analysis. For this reason, the survival rate estimated in the present study should not be extrapolated to the general population. It is safe to assume, however, that the cumulative survival rate reported herein might be underestimated.

A lack of external validity is also explained by the absence of machined-surface implants. In this way, it was not possible to calculate the survival rates adjusted for the type of implant surface. Nonetheless, high survival rates have been reported for both machined (Sjostrom et al., 2007; De Bruyn et al., 2013) and rough surface (Sbordone et al., 2009a; Fretwurst et al., 2015) implants placed in iliac crest autogenous grafts. Therefore, the impact of implant surface characteristic might be less evident than the influence of gender on implant survival.

Notwithstanding the fact that the present study aimed to evaluate the survival rate, another limitation is related to the absence of implant success rate analysis. The reason was the lack of adequate standardized radiographs taken at specific follow-up evaluations in order to calculate the mesial and distal marginal bone resorption with repeatable measurements. Due to the absence of serial standardized radiographs, it was not possible to judge an implant as successful or not, irrespective of the threshold adopted.

5. Conclusion

Within the limitations of the present study, the results suggested that rough surface implants placed in bone augmented with autogenous iliac crest onlay block grafts might be considered a reliable and predictable treatment option to rehabilitate patients with implant-supported rehabilitations. A survival rate of 91.1% over a median survival time of 312 months demonstrated that results could be maintained over long-term periods. The outcome was not influenced by the age of the patients and the surgical site. Conversely, cement-retained restorations showed significantly lower survival rates compared to screw-retained prostheses.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jcms.2019.02.002>.

Conflicts of interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

References

Aghaloo TL, Misch C, Lin GH, Iacono VJ, Wang HL: Bone augmentation of the edentulous maxilla for implant placement: a systematic review. *Int J Oral Maxillofac Surg* 31: s19–s30, 2016

Boven GC, Meijer HJ, Vissink A, Raghoobar GM: Reconstruction of the extremely atrophied mandible with iliac crest onlay grafts followed by two endosteal implants: a retrospective study with long-term follow-up. *Int J Oral Maxillofac Surg* 43: 626–632, 2014

Cawood JJ, Howell RA: A classification of the edentulous jaws. *Int J Oral Maxillofac Surg* 17: 232–236, 1988

Chiapasco M, Casentini P: Horizontal bone-augmentation procedures in implant dentistry: prosthetically guided regeneration. *Periodontol* 77: 213–240, 2018

Dasmah A, Thor A, Ekstubbe A, Sennerby L, Rasmusson L: Particulate vs. block bone grafts: three-dimensional changes in graft volume after reconstruction of the atrophic maxilla, a 2-year radiographic follow-up. *J Craniomaxillofac Surg* 40: 654–659, 2012

De Bruyn H, Bouvry P, Collaert B, De Clercq C, Persson GR, Cosyn J: Long-term clinical, microbiological, and radiographic outcomes of Branemark implants installed in augmented maxillary bone for fixed full-arch rehabilitation. *Clin Implant Dent Relat Res* 15: 73–82, 2013

de Groot RJ, Oomens M, Forouzanfar T, Schulten E: Bone augmentation followed by implant surgery in the edentulous mandible: a systematic review. *J Oral Rehabil* 45: 334–343, 2018

Fretwurst T, Nack C, Al-Ghrai M, Raguse JD, Stricker A, Schmelzeisen R, et al: Long-term retrospective evaluation of the peri-implant bone level in onlay grafted patients with iliac bone from the anterior superior iliac crest. *J Craniomaxillofac Surg* 43: 956–960, 2015

Garber DA, Belsler UC: Restoration-driven implant placement with restoration-generated site development. *Compend Contin Educ Dent* 16(796): 798–802, 1995

Gultekin BA, Cansiz E, Borahan MO: Clinical and 3-dimensional radiographic evaluation of autogenous iliac block bone grafting and guided bone regeneration in patients with atrophic maxilla. *J Oral Maxillofac Surg* 75: 709–722, 2017

Kotsakis GA, Zhang L, Gaillard P, Raedel M, Walter MH, Konstantinidis IK: Investigation of the association between cement retention and prevalent peri-implant diseases: a cross-sectional study. *J Periodontol* 87: 212–220, 2016

Kozlovsky A, Tal H, Laufer BZ, Leshem R, Rohrer MD, Weinreb M, et al: Impact of implant overloading on the peri-implant bone in inflamed and non-inflamed peri-implant mucosa. *Clin Oral Implant Res* 18: 601–610, 2007

Maiorana C, Santoro F: Maxillary and mandibular bone reconstruction with hip grafts and implants using Frialit-2 implants. *Int J Periodontics Restorative Dent* 22: 221–229, 2002

Moses O, Nemcovsky CE, Langer Y, Tal H: Severely resorbed mandible treated with iliac crest autogenous bone graft and dental implants: 17-year follow-up. *Int J Oral Maxillofac Surg* 22: 1017–1021, 2007

Naert I, Duyck J, Vandamme K: Occlusal overload and bone/implant loss. *Clin Oral Implants Res* 23(Suppl. 6): 95–107, 2012

Nelson K, Ozyuvaci H, Bilgic B, Klein M, Hildebrand D: Histomorphometric evaluation and clinical assessment of endosseous implants in iliac bone grafts with shortened healing periods. *Int J Oral Maxillofac Surg* 21: 392–398, 2006

Nystrom E, Nilson H, Gunne J, Lundgren S: A 9–14 year follow-up of onlay bone grafting in the atrophic maxilla. *Int J Oral Maxillofac Surg* 38: 111–116, 2009

Putter TF, Wortmann DE, Schortinghuis J, van Minnen B, Boven GC, Vissink A, et al: Morbidity of anterior iliac crest and calvarial bone donor graft sites: a 1-year randomized controlled trial. *Int J Oral Maxillofac Surg* 47: 1474–1480, 2018

Quaranta A, Lim ZW, Tang J, Perrotti V, Leichter J: The impact of residual subgingival cement on biological complications around dental implants: a systematic review. *Implant Dent* 26: 465–474, 2017

Raghoobar GM, Schoen P, Meijer HJ, Stellingma K, Vissink A: Early loading of endosseous implants in the augmented maxilla: a 1-year prospective study. *Clin Oral Implants Res* 14: 697–702, 2003

Renvert S, Persson GR, Piri FQ, Camargo PM: Peri-implant health, peri-implant mucositis, and peri-implantitis: case definitions and diagnostic considerations. *J Clin Periodontol* 45(Suppl. 20): S278–S285, 2018

Sakkas A, Wilde F, Heufelder M, Winter K, Schramm A: Autogenous bone grafts in oral implantology—is it still a “gold standard”? A consecutive review of 279 patients with 456 clinical procedures. *Int J Implant Dentistry* 3(23), 2017

Sbordone C, Toti P, Guidetti F, Califano L, Bufo P, Sbordone L: Volume changes of autogenous bone after sinus lifting and grafting procedures: a 6-year computerized tomographic follow-up. *J Cranio-Maxillofacial Surg* 41: 235–241, 2013

Sbordone C, Toti P, Guidetti F, Califano L, Santoro A, Sbordone L: Volume changes of iliac crest autogenous bone grafts after vertical and horizontal alveolar ridge augmentation of atrophic maxillas and mandibles: a 6-year computerized tomographic follow-up. *J Oral Maxillofac Surg* 70: 2559–2565, 2012

Sbordone L, Toti P, Menchini-Fabris G, Sbordone C, Guidetti F: Implant survival in maxillary and mandibular osseous onlay grafts and native bone: a 3-year clinical and computerized tomographic follow-up. *Int J Oral Maxillofac Surg* 41: 695–703, 2009a

Sbordone L, Toti P, Menchini-Fabris GB, Sbordone C, Piombino P, Guidetti F: Volume changes of autogenous bone grafts after alveolar ridge augmentation of atrophic maxillae and mandibles. *Int J Oral Maxillofac Surg* 38: 1059–1065, 2009b

Scheerlinck LM, Muradin MS, van der Bilt A, Meijer GJ, Koole R, Van Cann EM: Donor site complications in bone grafting: comparison of iliac crest, calvarial, and mandibular ramus bone. *Int J Oral Maxillofac Surg* 28: 222–227, 2013

Schwarz F, Derks J, Monje A, Wang HL: Peri-implantitis. *J Periodontol* 89(Suppl. 1): S267–S290, 2018

Sjostrom M, Sennerby L, Nilson H, Lundgren S: Reconstruction of the atrophic edentulous maxilla with free iliac crest grafts and implants: a 3-year report of a prospective clinical study. *Clin Implant Dent Relat Res* 9: 46–59, 2007

Sonmez TT, Prescher A, Salama A, Kanatas A, Zor F, Mitchell D, et al: Comparative clinicoanatomical study of ilium and fibula as two commonly used bony donor sites for maxillofacial reconstruction. *Br J Oral Maxillofac Surg* 51: 736–741, 2013

- Staubli N, Walter C, Schmidt JC, Weiger R, Zitzmann NU: Excess cement and the risk of peri-implant disease - a systematic review. *Clin Oral Implant Res* 28: 1278–1290, 2017
- Tosun E, Avag C, Baslarli O, Kiris S, Ozturk A, Akkocaoglu M: Comparison between peri-implant bone level changes of implants placed during and 3 months after iliac bone grafting. *Oral Surg Oral Med Oral Pathol Oral Radiol* 125: e12–e16, 2018
- van der Meij EH, Blankestijn J, Berns RM, Bun RJ, Jovanovic A, Onland JM, et al: The combined use of two endosteal implants and iliac crest onlay grafts in the severely atrophic mandible by a modified surgical approach. *Int J Oral Maxillofac Surg* 34: 152–157, 2005
- Vermeeren JJ, Wismeijer D, van Waas MA: One-step reconstruction of the severely resorbed mandible with onlay bone grafts and endosteal implants. A 5-year follow-up. *Int J Oral Maxillofac Surg* 25: 112–115, 1996