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Trends in techniques to avoid bone augmentation surgery: Application of short implants, narrow-diameter implants and guided surgery

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ABSTRACT

Introduction: Minimally invasive implantology using reduced implant dimensions as well as virtual treatment planning and CAD/CAM stereolithographic templates has gained popularity in recent years. The aim of the present investigation was to analyze prevailing trends in clinical utilization of these graftless therapeutic options.

Material and methods: A total of 12.865 dental implants were placed in 5.365 patients at the Academy for Oral Implantology in Vienna, of which 5.5% were short (length < 10 mm), 19.5% narrow (diameter < 3.75 mm) and 10.6% template-guided. Application trends were analyzed using linear regression and compared between jaw location and dentition subgroups.

Results: Use of short implants and guided surgery increased significantly in all subgroups. Narrow-diameter implants were most frequent in single-tooth gaps (24.1%), however, upward trends could only be observed in partially and completely edentulous patients. Short implants were predominantly used in the mandible (9.9% vs. 2.5%, $P < 0.001$) while guided surgery was favored in the maxilla (14.2% vs. 5.4%, $P < 0.001$).

Conclusion: Short implants (most frequent in partial edentulism) and guided implant surgery (most frequent in complete edentulism) represent uprising and promising surgical approaches to avoid patient morbidity associated with bone graft surgery.

1. Introduction

Osseointegrated dental implants represent a highly predictable and widespread therapy for rehabilitation of the incomplete dentition with long-term implant success rates of up to 97% (Busenlechner et al., 2014). In oral health care there has been an obvious trend during the past decade towards techniques to provide optimum service for patients yet with the minimal amount of treatment (Christensen, 2005). In the field of oral implantology, in particular, interest in minimally invasive surgical procedures as a standard treatment is notably growing (Papaspyridakos et al., 2012). Per definition, the option of a minimally invasive technique appeals to a greater number of potential implant patients and is also frequently associated with economic benefits (Gibney, 2001). Modification of the patient's jaw anatomy via bone augmentation surgery to allow placement of longer and wider implants (or a greater number of implants) in optimized locations has been generally considered the best treatment strategy in the past (Renouard and Nisand, 2006), however, adaptation of implant dimensions and positions to the prevailing patient anatomy may represent an alternative approach in cases of severe atrophy of the residual alveolar bone (Cho et al., 2007; Pommer et al., 2012; Sivolella et al., 2013; Esposito et al., 2015). Implant surgery is termed “minimally invasive” referring to avoidance of bone grafts (Scotti et al., 2010; Nkenke and Neukam, 2014), and/or prevention of intra- and postoperative patient morbidity in terms of pain (Fortin et al., 2006), swelling (Balshi et al., 2006), bleeding (Brodala, 2009), or expended operating time (Erickson et al., 1999).

Bone augmentation surgery may be avoided either by reduction of the size of implants used, i.e. application of short and narrow-diameter implants (Javed and Romanos, 2015; Sanz et al., 2015; Nedir et al., 2016), or else by guided implant surgery via virtual treatment planning software and CAD/CAM surgical templates (Pommer et al., 2014a). These techniques aim to circumvent bone

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grafting procedures by maximum use of the residual alveolar ridge as well as anatomical buttresses and are frequently associated with tilted implant positioning (Krekmanov et al., 2000) and flapless implant insertion (Pommer and Watzek, 2009). As apparent from the quantity of systematic reviews and meta-analyses on these topics (Lee et al., 2014; Monje et al., 2013; Klein et al., 2014; Ortega-Oller et al., 2014; Nickenig et al., 2012; Schneider et al., 2009), avoidance of bone grafts has undoubtably gained popularity, however, detailed insights into paradigm changes are not available to date. Furthermore, it has never been investigated whether treatment trends and clinical results are related to jaw location (maxilla or mandible) or the state of dentition (single-tooth gaps, partial or complete edentulism). Thus, the aim of the present study was to analyze clinical utilization as well as survival of short implants, narrow-diameter implants and guided implant placement.

2. Materials and methods

2.1. Patients and implants

In 5.365 patients (3.142 woman, 2.223 men, mean age: 58.6 years, age range: 18–102 years) a total of 12.865 dental implants were placed at the Academy for Oral Implantology (Vienna, Austria) in the years 2005–2012. Implants from various manufacturers were used (mainly Nobel Biocare, Gothenburg, Sweden; Dentsply, Mannheim, Germany; and Biomet 3i, West Palm Beach, FL, USA). Short implants were defined as less than 10 mm in length (Pommer et al., 2011), resulting in a total of 708 implants of reduced length (implant length ranging between 5.0 and 9.5 mm) corresponding to 5.5% of all fixtures placed. Short implants were applied mainly in posterior regions presenting with advanced crestal bone resorption or pneumatization of the maxillary sinus. The threshold for reduced implant diameter was set as below 3.75 mm in width (Degidi et al., 2008), thus a total of 2.509 implants were classified as narrow-diameter implants (implant diameters ranging between 3.0 and 3.5 mm) corresponding to 19.5% of all fixtures placed. Reduced implant diameters were used in cases of horizontal bone loss, i.e. compromised buccopalatal alveolar dimension, as well as single-tooth gaps in the central incisor (16.3%), lateral incisor (30.1%), canine (6.4%), first premolar (26.7%), second premolar (17.7%) or molar region (2.8%). Guided implant surgery was performed using cone-beam computed tomographic scans (Classic i-CAT, Imaging Sciences International, Hatfield, PA, USA, 0.25 voxel mode, high resolution) via the double scan technique (Fürhauser et al., 2015), computer-assisted implant treatment planning software (Nobel-Clinician™, Nobel Biocare, Gothenburg, Sweden) and custom surgical templates with precision titanium tubes (NobelGuide™, Nobel Biocare, Gothenburg, Sweden). A total of 1.362 implants were placed using guided surgery corresponding to 10.6% of all fixtures placed. Guided surgery was performed in edentulous cases to optimize the anterior-posterior spread as well as in the esthetic zone to avoid elevation of mucoperiosteal flaps. Regarding suprastructures, fixed cross-arch bridges were used in 96.6% of edentulous cases (the remainder receiving overdentures) and partially edentulous patients were restored via fixed partial dentures in 86.9% and single crowns in 13.1%.

2.2. Statistical analysis

Absolute and relative application frequencies were computed based on the total number of implants placed as well as the total number of patients treated. Trends over the years 2005–2012 were analyzed using linear regression with publication year as predictor variable and implant-based relative application frequency as response variable for the total sample of short, narrow and guided implants as well as for the following subgroups: maxillary vs. mandibular implants and implants in single-tooth gaps, partial or complete edentulism. Multiple r-squared (R^2) was computed to assess precision of model fit and the slope of linear relationship (m) was used to evaluate mean percentage change per year. In addition, implant survival rates were produced and subgroup comparison was performed via chi-square tests using absolute frequencies. Related P values were considered statistically significant below a level of 0.05. Information regarding implant survival was entered into a database (impDAT software, version 3.58, Kea Software GmbH, Pöcking, Germany) based on routine recall examinations. All calculations were performed using R-project statistical software (R Foundation for Statistical Computing, Vienna, Austria, Version 3.1.0).

3. Results

The use of short implants increased significantly from 0.8% of implants in 2005 to 8.7% in 2012 ($R^2 = 0.90$, m = 1.1, $P < 0.001$, Table 1) corresponding to 1.1%, 5.6%, 5.5%, 6.2%, 9.0%, 12.1%, 13.4% and 15.3% of patients treated, respectively (9.6% overall). In the maxilla 2.5% of implants were short (increase from 0.4% in 2005 to 4.9% in 2012) and 9.9% in the mandible (increase from 1.3% in 2005 to 15.3% in 2012) showing significant differences between the jaws ($P < 0.001$). Short implants in single-tooth gaps, partially and completely edentulous patients accounted for 4.8%, 9.7% and 1.8%, respectively (Fig. 1a) revealing significant differences regarding state of dentition ($P < 0.001$). Significant increase of the percentage of short implants could be observed in all subgroups (Table 2).

The use of narrow-diameter implants did not demonstrate significant changes between 2005 and 2012 ($R^2 = 0.26$, m = −1.2, $P = 0.193$) and averaged 20.1% ± 3.0% of fixtures placed (Table 1) corresponding to 33.9%, 34.9%, 34.2%, 28.6%, 28.9%, 28.3%, 23.6% and 26.0% of patients treated, respectively (28.9% overall). In the maxilla 22.5% of implants were narrow (33.0% in 2005 and 20.4% in 2012, no significant trend) and 15.2% in the mandible (13.8% in 2005 and 13.4% in 2012, no significant trend) showing significant differences between the jaws ($P < 0.001$). Narrow-diameter implants in single-tooth gaps, partially and completely edentulous patients accounted for 24.1%, 20.5% and 15.9%, respectively (Fig. 1b) revealing significant differences regarding state of dentition ($P < 0.001$). Significant increase of the percentage of narrow implants could be observed only in partially and completely edentulous patients (Table 2).

The use of guided implant surgery increased significantly from 1.5% of implants in 2005 to 10.5% in 2012 ($R^2 = 0.51$, m = 1.3, $P = 0.046$, Table 1) corresponding to 3.0%, 6.4%, 6.0%, 8.9%, 8.2%, 9.9%, 9.8% and 11.9% of patients treated, respectively (8.6% overall). In the maxilla 14.2% of implants were placed template-guided (increase from 2.8% in 2005 to 12.9% in 2012) and 5.4% in the mandible (increase from 0.0% in 2005 to 6.2% in 2012) showing significant differences between the jaws ($P < 0.001$). Guided implants in single-tooth gaps, partially and completely edentulous patients accounted for 5.6%, 6.3% and 18.1%, respectively (Fig. 1c) revealing significantly higher application frequency in edentulous jaws ($P < 0.001$), however, no difference between single-tooth gaps and partially edentulous patients ($P = 0.335$). Significant increase of

Table 1
Application of short, narrow and guided implants: implant-based percentages of all fixtures placed between 2005 and 2012.

	2005	2006	2007	2008	2009	2010	2011	2012
Short implants	0.8%	3.6%	3.2%	3.1%	4.8%	7.9%	8.1%	8.7%
Narrow implants	24.0%	23.5%	22.9%	19.7%	18.4%	19.1%	15.0%	17.8%
Guided implants	1.5%	9.2%	7.8%	10.4%	13.5%	9.3%	16.7%	10.5%