CLINICAL ORAL IMPLANTS RESEARCH

Keyvan Sohrabi
Ammar Mushantat
Shahrokh Esfandiari
Jocelyne Feine

Review Article

How successful are small-diameter implants? A literature review

Authors' affiliations:
Keyvan Sohrabi, Deptartment of Oral Health Policy and Epidemiology, Harvard School of Dental Medicine, Boston, MA, USA
Ammar Mushantat, Shahrokh Esfandiari, Jocelyne Feine, Oral Health and Society Research Unit, McGill University, Faculty of Dentistry, Montreal, QC, Canada
Jocelyne Feine, Department of Epidemiology and Biostatistics, McGill University, Faculty of Medicine, Montreal, QC, Canada

Corresponding author:
Jocelyne Feine, DDS, MS, HDR, FCAHS
Oral Health and Society Research Unit
3350 University Street, Suite 101
Montreal, Quebec, Canada H3A 2A7
Tel.: 514 398 7203
Fax: 514 398 8900
e-mail: jocelyne.feine@mcgill.ca

Key words: small-diameter implants, flapless surgery, survival rate, edentulism

Abstract

Background: Edentulism is an important issue and will remain so due to high numbers of edentate individuals worldwide. For many years, complete dentures have been the only treatment option for this population. Implant overdentures have been shown to have many advantages over conventional complete dentures. However, although dissatisfied with their mandibular dentures, some edentate elders are reluctant to undergo even simple implant treatment due to factors such as cost and fear of surgery. To address these obstacles, this paper reports on a review of small-diameter implant (SDI) studies that were performed in the last two decades. The aim of this study is to (i) determine the survival of narrow diameter implants, (ii) determine whether survival is dependent on whether these implants are placed using a flap or flapless approach, and (ii) determine whether there is a relationship between length and implant survival in SDIs.

Methods: In this review, studies were included that (i) involve implants with 3.5 mm diameter or less, (ii) have a randomized clinical trial, retrospective or prospective cohort design with human subjects, (iii) provide a follow up duration of at least 5 months following implant placement, (iv) include data on the survival rate of the implants.

Results: Forty one studies meeting the above criteria were published between 1993 and 2011 using SDIs from a variety of companies and surface characteristics with diameters of 1.8 mm to 3.5 mm and lengths of 8 mm to 18 mm. A total of 10,093 SDIs were inserted in approximately 2762 patients. Twenty-six studies involved flap reflection techniques for implant placement, six studies used a flapless technique and two studies used both techniques; in the remaining studies, the technique was not specified. Follow up duration varied from 5 months to over 9 years. The survival rate reported in all screened studies was over 90%, including eight studies in which a 100% survival rate was reported. In 22 studies, the reported survival rate ranged from 95% to 99.9%. Failure was reported most often in short SDIs (less than or equal 13 mm) (n = 88) compared to longer ones (more than 13 mm).

Conclusion: Survival rates reported for SDI are similar to those reported for standard width implants. These survival rates did not appear to differ between studies that used flapless and flap reflection techniques. The failure rate appeared to be higher in shorter SDIs than in longer ones in the studies in which the length of the failed implants was reported. SDIs could be considered for use with fixed restorations and mandibular overdentures, since their success rate appears to be comparable to that of regular diameter implants. They might also be an efficient, low-cost solution for elders who wish to reduce problems with denture instability.

Introduction

According to the World Health Organization, edentulism has an important adverse impact on the individual and, in some cultures, on the community, as well (World Health Organisation (WHO), 2000). Although complete denture prostheses are available to edentate populations, these devices cause many wearers difficulties. They lack stability and retention so that many people cannot chew hard or tough foods and, in some, the dentures move, which can cause pain, food impaction and loosening in a social context. Most problems occur with the mandibular denture, because of resorption of the bone, as well as movement of the tongue, cheeks and lips. Even denture-wearers who are able to wear an upper denture without problems often have difficulties eating with the lower denture (Muller et al. 2001). However, for many years, complete dentures have been the only treatment option for edentate individuals.

Implant overdentures provide better retention than conventional complete dentures which then substantially reduces difficulties

Date:
Accepted 18 December 2011

To cite this article:
Sohrabi K, Mushantat A, Esfandiari S, Feine J. How successful are small-diameter implants? A literature review. *Clin. Oral Impl. Res.* **00,** 2012, 1–11
doi: 10.1111/j.1600-0501.2011.02410.x

in function (Meijer et al. 2004). It has been shown that implants significantly reduce the amount of bone loss, the severity of peri-implant ridge resorption, denture instability, pain and sore spots, leading to improved masticatory efficiency and ability (Polzer et al. 2010). Apart from these improvements, several investigations have shown the positive impact of implant support/retention on psychosocial parameters, speaking ability, self-image and denture satisfaction (Cibirka et al. 1997; Wismeijer et al. 1997; Awad et al. 2000; Heydecke et al. 2003; Thomason et al. 2007). Results from a recent meta-analysis of clinical trials on implant overdentures have demonstrated that, compared to conventional complete dentures, mandibular overdentures can be effective treatments for edentate patients, based on patient ratings of satisfaction and oral health-related quality of life (Emami et al. 2009). The overwhelming evidence in support of implant overdentures led to the McGill Consensus Statement and, more recently, to the York Consensus Statement, both of which declare that mandibular two-implant overdentures be considered "as the first choice standard of care for edentulous patients" (Feine et al. 2002; Thomason et al. 2009).

Obstacles to implant treatment

Nevertheless, there are several obstacles to the implant option for the edentate patient: First, implant treatment is expensive, and edentate patients are often unable or unwilling to pay (Owen, 2004; Narby et al. 2008; Carlsson and Omar, 2010). It has been reported that, although 10% of the world's population is edentate, only 1.7% have received implant treatment(Carlsson and Omar, 2010).

Although cost is a significant barrier against implant treatment for the edentate population, other important obstacles, such as fear of surgery, play an important role. The largest group of edentate individuals is composed of those aged 65+ years. These elders are often anxious about any surgery (Kiyak et al. 1990). In a prospective study of a group of edentate elders (65+ years) who were offered free implants for mandibular overdentures, more than one third (36%) refused to have them. The most common reason for refusal of the implant therapy was a fear of surgical risks (43%) (Walton and MacEntee, 2005). This rejection of implant treatment should be seriously considered, since even the elimination of financial barriers did not persuade these elders to accept implants. In an attempt to explore the major factors that can affect the decision to replace failed implants, a study of 194 patients showed that, besides the cost issue, the main reason patients avoid re-implantation was the fear of additional pain (Mardinger et al. 2008). To gain a greater in-depth understanding of why elderly patients who are currently dissatisfied with conventional dentures decline implant treatment, a recent multicenter qualitative study of edentate patients in the UK and Canada revealed that fear and anxiety relating to potential pain or complications from surgery is a main theme in declining this type of treatment(Ellis et al. 2011).

Addressing the obstacles

The major obstacles against implant therapy for edentate patients, the issues of cost and fear of surgery, have been discussed. However, what remains to be done now is to overcome these obstacles in order to make implant therapy more accessible and less fearful to this large percentage of the edentate population.

To address the issue of fear, one might consider eliminating the need for flap reflection. Conventional flap-raising procedures are uncomfortable for patients both during and following surgery, while minimally invasive (flapless) procedures are designed to minimize discomfort from surgery by avoiding traumatic injury to the tissues. Flapless procedures may reduce surgical time, which could also reduce costs. Of course, the smaller the dimensions of the implants, the less likely it might be that a flapless placement would fail. Therefore, in an initial step to determine whether small-diameter implants (SDIs) can be placed using flapless procedures, we decided to carry out a literature review to (i) determine the survival of small (narrow) diameter implants, (ii) determine whether their survival is dependent on whether the implants are placed using a flap or flapless approach, and (iii) determine whether there is a relationship between length and implant survival.

Methods

Search strategy and eligibility criteria

PubMed, EMBASE, and Cochrane Database of Systematic Reviews up to August 2011 were searched for all peer-reviewed studies evaluating the use of SDIs. Searches were not restricted by publication date. Both keywords and MeSH terms were used in the electronic search. Key words used for search were "small diameter implant", "narrow diameter implant" and "mini dental implant". In addition to these databases, the reference lists of articles obtained by the electronic search, reference lists of review articles, and major implant journals (Clinical oral Implants Research, Clinical Implant Dentistry and Related Research, Implant Dentistry and International Journal of Oral & Maxillofacial Implants) were searched manually for relevant articles. No language restrictions were applied. During the review process, we contacted experts and companies involved in this area of research to find other trials or unpublished material. The corresponding authors of studies were contacted to clarify ambiguous or missing data.

To be included in this review, studies were required to (i) involve implants with 3.5 mm diameter or less, (ii) be a randomized clinical trial, retrospective or prospective cohorts in human subjects (iii) provide a follow up duration of at least 5 months following implant placement, (iv) include data with regards to the survival rate of the implants.

The following studies were excluded (i) case reports, reviews, non-clinical studies, explanation of technique or manuals (ii) mini-implants for orthodontic anchorage (iii) animal studies (iv) small-diameter implants that were not meant for permanent use i.e., fixation of temporary crown and bridges

Titles and abstracts, and full-texts when necessary, were screened for eligibility and confirmed by a second reviewer. In the case of discordance between reviewers, consensus was reached by discussion.

Data extraction

Data extraction was performed independently for each eligible study by at least two reviewers using a standardized form. The following variables were extracted from each study: study outcomes (survival rates), study design (randomized trials, prospective or retrospective cohort), patient demographics (age and sex), inclusion and exclusion criteria, year of publication, setting and country of intervention, follow up duration, Implant type and manufacturer, Implant surface charectristics, total number of implants placed and the number of implants in each patients, jaw segments (Anterior and Posterior site of Maxilla and Mandible), restoration type (Single Fixed, Fixed Partial, or overdentures), percentage of edentate subjects, type of surgery (flapless or not), number of implant failures in each patient and total number of failures.

Results

According to the search strategy explained in the methods, 41 studies published between 1993 and 2011 were selected in this review. Our PubMed search contained 39 of these studies, while 2 studies (including one abstract) were obtained through manual searching of the literature (Jorneus, 1996; Terpelle and Khoury, 2008). The search in EMBASE and Cochrane Database of Systematic Reviews did not reveal any new studies. (Table 1)(Block and Kent, 1993; Spiekermann et al. 1995; Jorneus, 1996; Lazzara et al. 1996; Saadoun and Le Gall, 1996; Sethi et al. 1996; Polizzi et al. 1999; Vigolo and Givani, 2000; Andersen et al. 2001; Hallman, 2001; Ahn et al. 2004; Mazor et al. 2004; Vigolo et al. 2004; Zinsli et al. 2004; Bulard and Vance, 2005; Comfort et al. 2005; Griffitts et al. 2005; Cordaro et al. 2006; Romeo et al. 2006; Zarone et al. 2006; Cho et al. 2007; Shatkin et al. 2007; Anitua et al. 2008; Reddy et al. 2008; Terpelle and Khoury, 2008; Veltri et al. 2008; Cochran et al. 2009; Degidi et al. 2009; Franco et al. 2009; Anitua et al. 2010; Jofre et al. 2010; Arisan et al. 2010; Huang et al. 2010; Jofre et al. 2010; Olate et al. 2010; Elsyad et al. 2011; Al-Nawas et al. 2011; Geckili et al. 2011; Malo and de Araujo Nobre, 2011; Morneburg and Proschel, 2008; Sohn et al. 2011). Due to the heterogeneity of the studies, no statistical analysis was performed.

Implant characteristics

Different implant brands were used (e.g. Branemark, IMTEC, ITI) with various diameters (1.8–3.5 mm), surface characteristics and lengths (8–18 mm). A total of 10,093 SDIs of various brands, diameters and lengths were inserted in 2762 patients. Some studies however, only reported the number of implants placed but not the number of patients. (Block and Kent, 1993; Lazzara et al. 1996; Saadoun and Le Gall, 1996; Sethi et al. 1996; Bulard and Vance, 2005; Anitua et al. 2008)

Patients' characteristics

Patients' ages ranged from 18 to 91 years, these patients presented with various health conditions. Medically compromised Patients (e.g. uncontrolled diabetes mellitus) were excluded from all studies. Eight studies included edentate patients (Ahn et al. 2004; Griffitts et al. 2005; Cho et al. 2007; Morneburg and Proschel, 2008; Veltri et al. 2008; Jofre et al. 2010; Al-Nawas et al. 2011; Elsyad et al. 2011), 14 studies included non-edentate populations (Polizzi et al. 1999; Vigolo and Givani, 2000; Andersen et al. 2001; Mazor et al. 2004; Vigolo et al. 2004; Cordaro et al. 2006; Romeo et al. 2006; Zarone et al. 2006; Degidi et al. 2008; Degidi et al. 2009; Reddy et al. 2008; Franco et al. 2009; Malo and de Araujo Nobre, 2011; Sohn et al. 2011), 7 studies included mixed populations (edentate and non-edentate)(Lazzara et al. 1996; Hallman, 2001; Zinsli et al. 2004; Comfort et al. 2005; Shatkin et al. 2007; Anitua et al. 2008; Cochran et al. 2009) and, in the remaining studies, the type of edentation was not specified (Block and Kent, 1993; Spiekermann et al. 1995; Jorneus, 1996; Saadoun and Le Gall, 1996; Sethi et al. 1996; Bulard and Vance, 2005; Terpelle and Khoury, 2008; Anitua et al. 2010; Arisan et al. 2010; Huang et al. 2010; Olate et al. 2010; Geckili et al. 2011) (See Table 1).

Surgical technique

Twenty six studies used flap reflection techniques for implants' placement (Lazzara et al. 1996; Saadoun and Le Gall, 1996; Sethi et al. 1996; Polizzi et al. 1999; Vigolo and Givani, 2000; Andersen et al. 2001; Hallman, 2001; Ahn et al. 2004; Mazor et al. 2004; Vigolo et al. 2004; Zinsli et al. 2004; Comfort et al. 2005; Romeo et al. 2006; Zarone et al. 2006; Anitua et al. 2008; Morneburg and Proschel, 2008; Veltri et al. 2008; Cochran et al. 2009; Degidi et al. 2009; Franco et al. 2009; Anitua et al. 2010; Arisan et al. 2010; Al-Nawas et al. 2011; Olate et al. 2010; Degidi et al. 2008; Malo and de Araujo Nobre, 2011); six studies used a flapless technique (Bulard and Vance, 2005; Griffitts et al. 2005; Cho et al. 2007; Shatkin et al. 2007; Jofre et al. 2010; Elsyad et al. 2011), two studies used both techniques (Reddy et al. 2008; Sohn et al. 2011) and, in the remaining studies, the technique was not specified (Block and Kent, 1993; Spiekermann et al. 1995; Jorneus, 1996; Saadoun and Le Gall, 1996; Cordaro et al. 2006; Huang et al. 2010; Geckili et al. 2011). In 10 studies, surgical location was reported to be in Mandible (Spiekermann et al. 1995; Ahn et al. 2004; Bulard and Vance, 2005; Griffitts et al. 2005; Cordaro et al. 2006; Cho et al. 2007; Morneburg and Proschel, 2008; Jofre et al. 2010; Al-Nawas et al. 2011; Elsyad et al. 2011), six studies in the Maxilla (Andersen et al. 2001; Hallman, 2001; Mazor et al. 2004; Zarone et al. 2006; Veltri et al. 2008; Degidi et al. 2009), and 20 studies were performed in both jaws (Lazzara et al. 1996; Sethi et al. 1996; Mazor et al. 2004; Vigolo et al. 2004; Zinsli et al. 2004; Comfort et al. 2005; Romeo et al. 2006; Shatkin et al. 2007; Anitua et al. 2008; Reddy et al. 2008; Cochran et al. 2009; Degidi et al. 2009; Franco et al. 2009; Anitua et al. 2010; Sohn et al. 2011; Arisan et al. 2010; Olate et al. 2010; Geckili et al. 2011; Malo and de Araujo Nobre, 2011; Degidi et al. 2008). In the remaining studies, the location was not specified.

Prosthesis design

In eight investigations, the implant prostheses used were mandibular overdentures(Ahn et al. 2004; Bulard and Vance, 2005; Griffitts et al. 2005; Cho et al. 2007; Morneburg and Proschel, 2008; Jofre et al. 2010; Al-Nawas et al. 2011; Elsyad et al. 2011), while the rest of the included studies were treated with variety of fixed, removable prostheses and overdentures (Single units, fixed bridges, removable partial denture and partial fixed). Two studies did not report the type of restoration(Block and Kent, 1993; Jorneus, 1996).

Follow up

Follow up duration varied from 5 months to over 9 years. Only one study (Griffitts et al. 2005) out of the 41 included studies reported patient-based outcomes. In this study, four subjective measures of patient's satisfaction were assessed (comfort, retention, chewing ability and speaking ability). The authors also discussed the financial advantages of SDIs.

Survival rate

The survival rate reported in all screened studies was over 90%, except for one study (Saadoun and Le Gall 1996) in which the survival rate was reported to be 89%. Eight studies reported a 100% survival rate (Sethi et al. 1996; Cordaro et al. 2006; Zarone et al. 2006; Veltri et al. 2008; Degidi et al. 2009; Huang et al. 2010; Jofre et al. 2010; Sohn et al. 2011), and in 23 studies, the survival rate ranged from 95% to 99.9% (Block and Kent, 1993; Spiekermann et al. 1995; Lazzara et al. 1996; Polizzi et al. 1999; Andersen et al. 2001; Hallman, 2001; Campelo and Camara, 2002; Ahn et al. 2004; Mazor et al. 2004; Vigolo et al. 2004; Zinsli et al. 2004; Comfort et al. 2005; Griffitts et al. 2005; Romeo et al. 2006; Anitua et al. 2008; Reddy et al. 2008; Franco et al. 2009; Anitua et al. 2010; Arisan et al. 2010; Malo and de Araujo Nobre, 2011; Al-Nawas et al. 2011; Geckili et al. 2011; Morneburg and Proschel, 2008). Only 13 out of 41 studies reported the length of the failed implants. A total of 104 implant failures (with their length data available) were reported. It was observed that failures occurred most often in implants with short length ($\leq$13 mm) (n = 88) compared to the long ones (>13 mm) (n = 16) used in the same

Table 1. **Characteristics of studies included in the review**

Citation/ Country	Study design/ Technique	Implant type	Implant diameter	Implant length	Surface characteristic	Number of implants/ Patients	Jaw segment	Edentulism	Restoration type	Age (years)	Failure/ length of failed implants	Follow up duration	Implants survival rate
Al-Nawas et al. (2011)/ Multicenter (Europe)	Randomized trial/Flap reflection	Straumann	3.3 mm	8 mm 10 mm 12 mm 14 mm	(SLActive) Sandblast, Large grit, Acid etched	178 implants 89 patients	Mandible	100% Edentate	Overdentures	65.81 (49–86)	3/NS	1 year	98%
Elsyad et al. (2011)/Egypt	Prospective/ Flapless	IMTEC	1.8	12 mm (7.1%) 14 mm (25%) 16 mm (36.6%) 18 mm (31.3%)	Sand blasted & acid-etched	112 implants 28 patients	Mandible	100% Edentate	Overdentures	62.9 (49–75)	4/4*14 mm	3 years	96.4%
Geckili et al. (2011)/ Turkey	Retrospective/ NS	Straumann Osseospeed Biolok Int Xive	3.3–3.5 mm	NS	Various	159 implants 71 patients	71 Maxilla 88 Mandible	NS	32 Overdentures 127 Fixed	NS	2/NS	5 years	98.70%
Malo and de Araujo Nobre (2011)/ Portugal	Retrospective/ Flap reflection	Branemark	3.3 mm	10 mm 11.5 mm 13 mm 15 mm	Machined surface VS TiUnite™ (TiO2)	247 implants 147 patients	144 Po. Maxilla 103 Po. Mandible	Most of the patients are non-edentate	Fixed	47.5 (26–77)	(12) 3*10 mm 2*11.5 mm 1*13 mm 3*15 mm	5 years (1–11)	95.10%
Sohn et al. (2011)/Korea	Retrospective/ Flap reflection and flapless	Biohorizons	3.00 mm	12 mm(3) 15 mm (59)	RBT body HA body	62 implants 32 Patients	8 Maxilla 54 Mandible	100% non-edentate	Fixed	52 (42–72)	0	23 ± 4.3 months	100%
Anitua et al. (2010)/Spain	Retrospective/ Flap reflection	Tiny®	2.5–3 mm	10 mm (8) 11.5 mm (9) 13 mm (41) 15 mm (31)	PRGF acid-etched surface	89 implants 51 Patients	66 Maxilla 23 Mandible	NS	30% overdenture 70% Fixed	54.8 (19–90)	1/NS	3 years	98.90%
Arisan (2010)/ Turkey	Retrospective/ Flap reflection	Straumann Xive	3.3 mm 3.4 mm	8–9.5 mm (33) 9.5–11 mm (83) 11–13 mm (113) 13–15 mm (87)	Sand blasting and acid etching	316 implants 139 patients	161 Maxilla 155 Mandible	NS	24 overdentures 96 Fixed	55.3 (21–80)	(14) 1*8 mm 6*9.5 mm 7*10 mm 1*13 mm	9.1 years	92.30%

Table 1. (continued)

Citation/ Country	Study design/ Technique	Implant type	Implant diameter	Implant length	Surface characteristic	Number of implants/ Patients	Jaw segment	Edentulism	Restoration type	Age (years)	Failure/ length of failed implants	Follow up duration	Implants survival rate
Huang et al. (2010)/China	Prospective/ NS	Osstem MS	2.5 mm 3.0 mm	NS	RBM	36 implants 36 patients	NS	NS	Fixed	NS	0	21 months	100%
Jofre et al. (2010)/Chile	Randomized trial/Flapless	IMTEC	1.8 mm	15 mm	Sand blasted & acid-etched	90 implants 45 patients	Mandible	100% Edentate	Overdentures	45–90	0	2 years	100%
Olate et al. (2010)/Brazil	Retrospective/ Flap reflection	Conexão SIN Neodent	3.3–3.5 mm	6–9 mm 10–12 mm 13–18 mm	Acidification	137 implants NS patients	109 Maxilla 26 Mandible	NS	Fixed Overdentures	42.7 (13–84)	7/NS	249 days	94.90%
Cochran et al. (2009)/ USA, UK	Prospective/ Flap reflection	Straumann	3.3–4.1 mm (Solid-Screw)(SS) 3.5 mm (Hollow-cylinder) (HC)	8 mm 10 mm 12 mm 14 mm 16 mm	Titanium plasma-sprayed	596 implants 192 patients	231(HC) Maxilla 365(SS) Mandible	Edentate and non-edentate	Fixed	51 (19–78)	NS	5 years	NS
Degidi et al. (2009)/Italy	Randomized trial/Flap reflection	XIVE	3.0 mm	13 mm 15 mm	Grit-blasted and acid-etched	60 implants 60 Patients	Anterior Maxilla	100% non-edentate	Single fixed	31.5 (18–55)	0	3 years	100%
Franco et al. (2009)/Italy	Retrospective/ Flap reflection	Various Types[1]	3–3.5 mm	10 mm 13 mm 16 mm	Various	94 implants 36 patients	75 Maxilla 16 Mandible	100% non-edentate	69 Fixed 7 Removable 15 None	53	(5) 2*10 mm 3*13 mm	25 months	95.70%
Terpelle and Khoury (2008)/ Germany	Retrospective/ NS	XIVE	3.0 mm 3.4 mm	NS	Grit blasted/ acid etched/ neutralized surface (FRIADENT plus)	337 implants 137 patients	NS	NS	Fixed	NS	2	3 years	99.40%
Anitua et al. (2008)/Spain	Retrospective/ Flap reflection	BTI®	2.5 mm 3.0 mm 3.3 mm	8.5 mm (46) 10.0 mm (118) 11.5 mm (102) 13.0 mm (263) 15.0 mm (358) 18.0 mm (24)	PRGF treated	911 implants NS Patients	53% Maxilla 47% Mandible	78% non-edentate 22% Edentate	Fixed Overdentures	54 (17–91)	(9) 3*10.0 mm 3*11.5 mm 2*15.0 mm 1*18.0 mm	28 months	99%

Table 1. (continued)

Citation/ Country	Study design/ Technique	Implant type	Implant diameter	Implant length	Surface characteristic	Number of implants/ Patients	Jaw segment	Edentulism	Restoration type	Age (years)	Failure/ length of failed implants	Follow up duration	Implants survival rate
Degidi et al. (2008)/Italy	Retrospective/ Flap reflection	Various Types	3–3.5 mm	Incisors (10–18 mm) (158) Canines (11–18 mm) (33) Premolars (9.5–18) (169) Molars (8–15 mm) (120)	Various	510 implants 237 patients	193 Maxilla 317 Mandible	100% non-edentate	Fixed	50 (18–80)	(3) 1*13 mm 1*15 mm 1*18 mm	20 months	99.40%
Morneburg and Proschel (2008)/ Germany	Prospective/ Flap reflection	Microplant	2.5 mm	9 mm(22) 12 mm (82) 15 mm (30)	Sand-plasted and CaP coated	134 implants 67 Patients	Mandible	100% Edentate	Overdentures	69 (53–83)	6/NS	6 years	95.50%
Reddy et al. (2008)/USA	Prospective, Case series/ Flapless and flap reflection	Biohorizons	3.0 mm	NS	Resorbable blast surface with square threads	31 implants 12 patients	Maxilla Mandible	100% non-edentate	Single fixed	19–74	1	1 year	96.70%
Veltri et al. (2008)/Italy	Prospective/ Flap reflection	Astra Tech	3.5 mm	9 mm 13 mm 15 mm 17 mm	TiO2-blasted	73 implants 12 patients	Maxilla	100% Edentate	Fixed	58 (42–74)	0	1 year	100%
Cho et al. (2007)/USA	Prospective/ Flapless	Dentatus	2.4 mm	7 mm 10 mm 14 mm	Conventional machined	34 implants 10 patients	Mandible	100% Edentate	Overdentures	58.25 (30–83)	2/NS	14–36 months	94%
Shatkin et al. (2007)/USA	Prospective/ Flapless	3M	1.8–2.4 mm	NS	Etched self-tapping thread	2514 implants 531 patients	50% Maxilla 50% Mandible	45% Edentate 55% non-edentate	45% Overdentures 55% Fixed	20–100	145/NS	2.9 years	94.20%
Cordaro et al. (2006)/ Italy	Retrospective/ NS	Straumann	3.5 mm	NS	Large-grit sandblasted and acid-etched	44 implants 31 Patients	Ant. Mandible	100% non-edentate	Single fixed	42.7 (13–84)	0	23 months	100%
Romeo et al. (2006)/Italy	Prospective/ Flap reflection	ITI	3.3 mm	10 mm 12 mm	Titanium plasma-sprayed (TPS)	122 implants 68 patients	Maxilla (56) Mandible (66)	100% non-edentate	23 Single fixed 99 Partial fixed	55.8 (21–74)	(3) 3*10 mm	7 years	98.1% (U) 96.9% (L)*

Table 1. (continued)

Citation/ Country	Study design/ Technique	Implant type	Implant diameter	Implant length	Surface characteristic	Number of implants/ Patients	Jaw segment	Edentulism	Restoration type	Age (years)	Failure/ length of failed implants	Follow up duration	Implants survival rate
Zarone et al. (2006)/Italy	Prospective/ Flap reflection	ITI	3.3 mm	9 mm(9) 12 mm (17) 14 mm(8)	Acid-etched and sand-plasted	34 implants 30 patient	Ant. Maxilla	100% non-edentate	Fixed	55.3 (21–80)	0	24–39 months	100%
Bulard and Vance (2005)/ USA	Prospective/ Flapless	IMTEC	1.8–2.4 mm	NS	Etched self-tapping thread	1029 implants	Mandible	NS	Overdentures	70	103	4 months to 8 years	91.17%
Comfort et al. (2005)/ Italy	Prospective/ Flap reflection	Branemark	3.3 mm	10 mm (10) 13 mm(5) 15 mm(8)	Machined screw-shaped	23 implants 9 patients	(3) Ant. Maxilla (6) Post. Mandible	70% non-edentate 30% Edentate	3 Fixed dentures 6 Fixed bridges	18–70	1/NS	5 years	96%
Griffitts et al. (2005)/USA	Prospective/ Flapless	IMTEC	1.8 mm	10–18 mm	Etched self-tapping thread	116 implants 30 patients	Ant. Mandible	100% Edentate	Overdentures	67 (50–90)	3/NS	5 months	97.40%
Ahn et al. (2004)/Korea	Prospective/ Flap reflection	IMTEC	1.8–2 mm	13 mm(6) 15 mm (19) 18 mm(2)	Etched self-tapping thread	27 implants 11 patients	Mandible	100% Edentate	Overdentures	52.9 (41–73)	1/NS	5.5 months	96.30%
Mazor et al. (2004)/Israel	Prospective/ Flap reflection	Hi-Tec	2.4 mm	13 mm	Integrated	32 implants 32 patients	Maxilla Mandible	100% non-edentate	Single fixed	NS	1/NS	5 years	96.8
Vigolo et al. (2004)/Italy	Retrospective/ Flap reflection	3i	2.9 mm 3.25 mm	8.5 mm (10) 10 mm (51) 11.5 mm (37) 13 mm (64) 15 mm (30)	Dual acid-etched	192 implants 165 patients	60% Maxilla Antr(68) Post(42) 40% Mandible Antr(50) Post(32)	100% non-edentate	94 Single fixed 98 Partial	39 (17–74)	(9) 8*10 mm 1*13 mm	7 years	95.30%
Zinsli et al. (2004)/ Switzerland	Prospective/ Flap reflection	ITI	3.3 mm	8 mm(60) 10 mm (126) 12 mm (112)	Tricalcium phosphate blasted	298 implants 154 patients	43% Maxilla 57% Mandible	(81%) Edentate (19%) non-edentate	120 Overdentures 57 Fixed	62 (19–87)	(9) 1*8 mm 3*10 mm 5*12 mm	6 years	96.60%
Andersen et al. (2001)/ Norway	Prospective/ Flap reflection	3i	3.25 mm	13 mm 15mm	Dual acid-etched	32 implants 28 Patients	Ant. Maxilla	100% non-edentate	Single fixed	23.2 (17–54)	2/NS	2 years	93.80%

Table 1. (continued)

Citation/ Country	Study design/ Technique	Implant type	Implant diameter	Implant length	Surface characteristic	Number of implants/ Patients	Jaw segment	Edentulism	Restoration type	Age (years)	Failure/ length of failed implants	Follow up duration	Implants survival rate
Hallman et al. (2001)/ Sweden	Prospective/ Flap reflection	ITI	3.3 mm	8 mm(17) 10 mm (85) 12 mm (58)	Tricalcium phosphate sprayed (TPS)	160 implants 40 patients	Maxilla	(77.5%) Edentate (22.5%) non-edentate	Various fixed	57 (20 to 86)	(1) 1*8 mm	1 year	99.4
Vigolo and Givani (2000)/ Italy	Retrospective/ Flap reflection	3i	2.9 mm	8.5 mm(1) 10 mm (20) 13 mm (22) 15 mm(9	Dual acid-etched	52 implants 44 patients	29 Maxilla 23 Mandible	100% non-edentate	Single fixed	35 (18–74)	(3) 2*10 mm 1*13 mm	5 years	94.20%
Polizzi et al. (1999)/Italy	Prospective/ Flap reflection	Brånemark	3.0 mm	10 mm(3) 13 mm (18) 15 mm(9)	Uniquely enhanced titanium oxide layer	30 implants 21 patients	Ant Maxilla	100% non-edentate	Single fixed	30 (13–58)	1/NS	1 year	96.70%
Lazzara et al. (1996)/USA	Retrospective/ Flap reflection	3i	3.3 mm	NS	Dual acid-etched (endosseous)	201 implants	120 Maxilla 82 Mandible	Edentate and non-edentate	Various fixed	18–82	8/NS	5 years	96%
Sethi et al. (1996)/ Europe	Prospective/ Flap reflection	Osteo Ti	2.75–3 mm	NS	Grit blasted and acid etched micro-textured	109 implants	48% Ant. Maxilla 13% AntMandible 39% Post. Mandible	NS	23 Single fixed 99 Partial fixed	NS	0	3 years	100%
Saadoun and Le Gall (1996)/ Europe	Prospective/ Flap reflection	Nobel Biocare	3.25 mm	8 mm(37) 10 mm (41) 12 mm (93) 14 mm (51) 16 mm (74)	Threaded titanium	306 implants	NS	NS	Various	NS	(34) 8 mm (21) 10 mm(3) 12 mm(6) 14 mm(2) 16 mm(2)	8 years	89%
Jorneus et al. (1996)/ Multicenter	NS	Branemark	3 mm	NS	Enhanced titanium oxide layer	201 implants 106 patients	NS	NS	NS	NS	7/NS	NS	93%
Spiekermann et al. (1995)/ Germany	Prospective/ NS	IMZ	3.3 mm	NS	HA-coated implant	127 implants 61 patients	Ant. Mandible	NS	Overdentures	60 (24–87)	7/NS	5.7 years	95%
Block and Kent (1993)/ USA	Retrospective/ NS	Integral	3.25 mm	NS	HA-coated	238 implants	43% posterior	NS	NS	NS	2/NS	8 years	99%

study. It was not possible to determine whether there were differences in implant survival rates based on surface characteristics (machined and rough); perhaps this was due to the fact that high survival rates were reported for all studies. We were unable to calculate survival rate using the patient, as opposed to individual implant, because these data were not always reported.

Fifteen studies with a total of 3043 inserted implants reported a minimal observation period of 5 years or more (Table 1). These studies included fixed restorations (single crowns and partial bridges), as well as mandibular overdentures. The survival rate reported for this period of observation ranged from 89% (Saadoun and Le Gall 1996) to 99% (Block and Kent 1993). The longest period of reported observation was 9.1 years (Arisan et al. 2010) with a survival rate of 92.3% for 316 implants placed in 139 patients. At the time of the present review, the most recent study with a minimum follow up of 5 years (Geckili et al. 2011) reported a survival rate of 98.7% for 159 narrow diameter implants inserted in 71 patients.

Mandibular overdentures

Seven studies involved the mandible of edentate patients. These studies (Ahn et al. 2004; Griffitts et al. 2005; Cho et al. 2007; Morneburg and Proschel, 2008; Jofre et al. 2010; Al-Nawas et al. 2011; Elsyad et al. 2011) included a total of 489 implants inserted in 207 patients. Patients' ages ranged between 30 and 90 years. Implants' diameters placed were 1.8–3.3 mm, and 7–18 mm in length. The surgical technique implemented was flapless in two out of the seven studies. The final prosthesis provided all studies were an implant overdenture with ball-clip attachment system. The Follow up period was 6 months to 6 years, with survival rate reported to be 94% to 98%.

Discussion

Small-Diameter Implants, Narrow-Diameter Implants or Mini-Dental Implants are all used to describe implants with diameters less than 4 mm. They were first introduced commercially in the dental field in 1990(Davarpanah et al. 2000). Since that time, several studies have been carried out using these implants, all of which are presently commercially available (both submerged and non-submerged) (Zinsli et al. 2004). The various designs of SDIs have become more commonly used in recent decades due limitations in the geometry and capacity of the alveolar bone (Olate et al. 2010). The main two advantages of SDIs are: (i) the ability to apply less invasive surgical procedures when there is circumferential bone deficiency around the implants, and (ii) the ability to place SDIs in reduced interradicular spaces, such as the edentulous ridge of the mandibular incisors (Olate et al. 2010; Elsyad et al. 2011).

As shown in the current review, the survival rate of small-diameter implants appears to be similar to that of regular diameter implants. In the current study, the majority of studies reported survival rates at 95–100%, and no study reported survival rates below 89%. Although most insertion techniques used to place implants require flap reflection to give practitioner better and clearer visibility, this is considered as an invasive approach (Fortin et al. 2006). Flap elevation to expose the surgical site may lead to trauma to the soft tissues, pain and subsequent bone resorption (al-Ansari and Morris, 1998; Oh et al. 2007). Flapless techniques have been recommended as the surgical protocol for both regular and SD implants. This flapless approach is considered to offer advantages over the traditional flap access approach. Bleeding may be minimized, as well as surgical times(Becker et al. 2005; Casap et al. 2005; Komiyama et al. 2008). Furthermore, no negative influence on implant survival has been reported with this technique (Berdougo et al. 2010; Mueller et al. 2011). Some studies even suggest that, with flapless implant surgery, patients' postoperative discomfort, such as swelling and pain, is almost negligible (Casap et al. 2005). Flapless insertion of dental implants prevents complications arising from soft-tissue elevation, such as infection, dehiscence and necrosis. Furthermore, flapless implant placement appears to provide dental implant success rates equal to conventional techniques (Berdougo et al. 2010). A recent histological study indicated that a flapless technique to insert implants has fewer inflammatory consequences and, thus, earlier re-epithlialization than using flap reflection techniques (Naert et al. 2002). Theoretically, a high success rate can be obtained by using this technique through careful patient selection and treatment planning. In this review, we found that there is no difference in the implants' survival rate between studies using the flapless and flap reflection techniques. However, only six studies in this review were performed using the flapless approach. Thus, more studies should be carried out using flapless techniques.

To our knowledge, this is one of the first studies that show the relationship between implant length and survival rate in SDIs. In fact, few studies have been carried out in this field. One result of this study was the finding that failure is accompanied with short implants more often than with longer ones (Weng et al. 2003; Feldman et al. 2004; Herrmann et al. 2005). While other studies have reported that implant length has no significant impact on survival rate (Sethi et al. 1996; Testori et al. 2001; Lemmerman and Lemmerman, 2005; Sun et al. 2011), these were carried out with regular diameter implants. Several factors may explain this controversy, such as the implant's primary stability, the quality of patient's bone and the practitioner's learning curve. In this SDI study, only 13 out of 40 studies reported the length of the failed implants. In those that did report implant length, the failure rate was higher in the shorter SDIs.

One of the major goals in oral public health promotion is to develop and test technologies that address oral health problems. We believe that lower income, elder denture wearers suffer important problems that could be addressed through better stabilization of their dentures. Thus, it is our role to promote the development and testing of low cost, minimally invasive implant therapies.

Summary and Conclusion

In this review, we aimed to understand the scientific evidence which exists regarding SDIs and their flapless placement. We found only a few studies in which flapless placement was carried out, but these studies suggest that SDIs placed using a flapless approach is successful. We also learned that there may be reduced success when these SDIs are of shorter length. More studies need to be carried out to provide additional rigorous scientific evidence to support this therapeutic paradigm. With cost of health care increasingly on the rise, along with greater needs from populations with limited incomes, low-cost solutions for denture stability should be a high priority for government, academic institutions, funding agencies, researchers and industry.

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