Survival Estimates and Risk Factors for Failure with 6 × 5.7-mm Implants

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Purpose: *Short dental implants facilitate prosthetic restoration in the setting of limited alveolar bone height. The study objectives were to (1) estimate the 1-year survival of Bicon 6 × 5.7-mm implants, (2) compare the 1-year survival of 6 × 5.7-mm implants with that of non–6 × 5.7-mm implants, and (3) identify risk factors associated with implant failure.* ***Materials and Methods:*** *A retrospective cohort study design was used. The sample was composed of patients who had received at least one 6 × 5.7-mm implant. Predictor variables were categorized as demographic, health status, anatomic, implant-specific, prosthetic, perioperative, and reconstructive. The outcome variable was implant failure, defined as explantation. Appropriate descriptive, bivariate, and multivariate survival statistics were computed.* ***Results:*** *The sample was composed of 35 patients in whom 172 implants had been placed (45 of which were 6 × 5.7-mm). The 1-year survival rates for 6 × 5.7-mm and non–6 × 5.7-mm implants were 92.2% and 95.2%, respectively (P = .76). After adjusting for covariates in a multivariate model, implant size was not associated with failure (P = .95).* ***Discussion:*** *The comparable survival estimates for 6 × 5.7-mm implants and non–6 × 5.7-mm implants in this study suggested that 6 × 5.7-mm implants can become osseointegrated and bear a functional load after placement.* ***Conclusions:*** *The survival of 6 × 5.7-mm implants was comparable to that of non–6 × 5.7-mm implants.* Int J Oral Maxillofac Implants 2005;20:930–937

Key words: *dental implants, implant survival, oral surgery, risk factors, short implants*

There have been many different approaches to solving the problem of prosthetic reconstruction involving severe atrophy of the alveolar ridge. The more aggressive protocols call for bone grafting followed by the placement of endosseous implants.[1–4] While these protocols have met with moderate success, many patients are unwilling to undergo or would like to avoid multiple surgical procedures. In the setting of reduced alveolar bone height, the short dental implants that have recently become available offer clinicians a pragmatic option to facilitate prosthetic restoration in the face of anatomic limitations.

The use of short implants (≤ 10 mm) has been a source of debate over the past decade. Some studies report higher failure rates with shorter implants.[5–16] Other studies report survival rates comparable to longer implants.[17–26] These conflicting results suggest the need for additional research efforts aimed at elucidating successful applications and recommendations for the use of short dental implants.

In bone of poor quantity and quality, some authors have suggested increasing implant diameter as a way to increase tolerance of occlusal forces, improve initial stability, and provide a favorable stress distribution to the surrounding bone.[27–31] Wider-diameter implants have shown favorable results in several studies, particularly in the posterior mandible.[29,30] Definitive recommendations regarding wider-diameter implants are lacking, and more research is needed.

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The purpose of this study was to report clinical outcomes of a short, wide-diameter dental implant 6 mm wide and 5.7 mm long (Bicon Dental Implants, Boston, MA). The authors believe that the combination of a short implant length with a wide diameter is a clinically acceptable option when indicated, and they hypothesized that this combination would result in survival rates equivalent to longer implants. The specific aims of this study were to estimate the survival of Bicon 6 × 5.7-mm implants, compare the survival of 6 × 5.7-mm implants with implants of other sizes, and identify risk factors associated with implant failure.

Fig 1 Example of 6.0 mm (wide) × 5.7 mm (long) implant used in the study.

MATERIALS AND METHODS

Study Design and Sample

A retrospective cohort design was used to address the aims of this study. The cohort was composed of patients having at least one 6 × 5.7-mm (diameter × length) Bicon implant (Fig 1) placed between January 27, 1997 and June 8, 2002 at the Implant Dentistry Centre at Faulkner Hospital (IDC-FH), Boston, MA. The IDC-FH is a teaching facility with clinicians ranging from junior clinicians to highly experienced faculty members. Most of the implants were placed and restored by experienced clinicians at the IDC-FH; a small percentage of the implants were placed by junior clinicians. Three clinicians, 2 oral and maxillofacial surgeons and 1 periodontist, placed the implants. Three different clinicians, 2 general restorative dentists and 1 prosthodontist, restored the implants. Institutional approval was obtained for the study.

For purposes of comparison, data also were collected for all implants placed in the cohort, including those that were not 6 × 5.7 mm. The sample was composed of patients who had charts available for review.

Study Variables

The major predictor variable was implant size. The implants were grouped into 2 categories: 6 × 5.7-mm and non–6 × 5.7-mm implants. Other study variables were grouped into the following categories:

- **Demographics:** The patient's age at implant placement and gender were variables in this category.
- **Health Status:** The American Society of Anesthesiology (ASA) system was used to classify general health status. Patients were categorized as being healthy (ASA 1), having mild systemic disease (ASA 2), or having moderate to severe systemic disease (ASA 3). If a condition existed in which wound healing was impaired, patients were categorized as being medically compromised. Conditions that caused a patient to be categorized as medically compromised included diabetes, liver disease, immunosuppressive disorders, chemotherapy, and radiation therapy. In addition, current and past tobacco use status was recorded.
- **Anatomy:** The anatomic variables were implant location (maxilla, mandible, anterior, posterior), implant proximity to teeth or other implants (no adjacent teeth, 1 adjacent tooth, 2 adjacent teeth, 1 adjacent implant, 2 adjacent implants, 1 adjacent tooth and 1 adjacent implant) and bone quality (types 1 to 4) were included in this category. Bone quality was ascertained clinically at the time of implant placement according to the clinicians' judgment. In general, following the withdrawal of an osteotomy reamer, an assessment of the bone in the flutes was conducted in terms of quantity and appearance. Bone quality was classified as type 1 if the bone was compact, near bloodless cortical bone. Type 2 bone was red and filled the flutes of the reamer. If no bone remained in the flutes, the bone quality was classified as type 4. If the findings were intermediate between those described for types 2 and 4, the bone was categorized as type 3.
- **Implant-Specific Variables:** These variables included implant length (5.7 to 14 mm), diameter (3 to 6 mm), coating (titanium plasma sprayed [TPS], hydroxyapatite [HA] -coated, uncoated), well size (2 to 3 mm), staging (1-stage or 2-stage), and immediate placement. A 2-stage surgery involved implant placement with soft tissue covering of a healing abutment in 1 surgery, followed by uncovering 4 to 6 months later. In 1-stage surgery the implant and healing abutment were left uncovered after implant placement. Immediate implants were placed on the same day of extraction of the tooth being replaced.

- **Prostheses:** The restoration of each implant was classified as a single crown, fixed partial denture, or removable prosthesis or overdenture.
- **Perioperative Treatment:** The perioperative use of antibiotics was assessed in this category.
- **Reconstructive Procedures:** For the purposes of this study, all of the reconstructive procedures were grouped together and treated as a homogenous group. Such procedures were coded as present or absent. Reconstructive procedures used to enhance the implant recipient site included internal or lateral sinus lifts, barrier membranes, autologous and synthetic bone-substitute grafting, and ridge split procedures.

Implant failure was the primary outcome variable in this study. Failure was defined as removal of the implant. For each implant, the date the implant was placed, the date the definitive restoration was placed, and the date of the patient's last visit were recorded. If applicable, the date of implant removal was recorded. The time between implant placement and patient's last visit or implant removal was defined as the duration of implant survival.

Data Analyses

Information was collected and entered into a database using Microsoft Excel. Data analyses were performed using SAS (SAS Institute, Cary, NC; version 8.2) and S-plus (MathSoft, Seattle, WA; version 6.0) statistical software. Appropriate uni-, bi-, and multivariate survival statistics were computed. Nonparametric Kaplan-Meier survival analyses were then used to determine the 1-year survival rates with associated 95% confidence intervals (CIs) for all 3 implant groups.[32,33] Bivariate analyses were performed using Cox proportional hazard regression analyses to determine candidate risk factors associated with implant failure ($P \leq .15$) for inclusion in a multivariate Cox model ($P \leq .05$) adjusted for clustering of implants.[34,35]

RESULTS

Between January 27, 1997, and June 8, 2002, 35 subjects had at least one 6 × 5.7-mm implant placed and were eligible for study inclusion. None of the implants were immediately loaded. A total of 172 Bicon implants were placed. Of the 172 implants, 45 (26%) measured 6 mm in length and 5.7 mm in diameter (6 × 5.7). The mean age at implant placement for the total implant group was 59.2 ± 12.0 years (based on 156 implants in 33 patients) and 53.5% of these implants were placed in men. Most patients (88.5%) were healthy or had mild systemic disease (ASA ≤ 2). Seven patients (20.0%) having 48 (27.9%) implants placed were classified as being medically compromised. Three of these patients had diabetes, 3 had received chemotherapy, and 1 had hepatitis. None of the patients were smokers.

For the total group of implants (n = 172), the most common location for placement was the posterior mandible (43.6%), followed by the posterior maxilla (34.3%), anterior maxilla (17.4%), and anterior mandible (4.7%). Implants were most commonly placed in proximity to 1 tooth and 1 implant (28.5%) and in type 4 bone (47.5%). An HA coating had been applied to 51.9% of the implants; 30.9% were coated with TPS, and 17.3% were uncoated. A majority of implants (60.2%) were placed in 2 stages, and only 20.4% were placed immediately following extraction of the tooth being replaced. The most common prosthesis used for restoration of these implants was the single crown (92.8%). In addition, 89.5% of the surgeries involved perioperative antibiotic use, and 18.0% of the surgeries involved some type of dentoalveolar reconstruction. The results are shown in Table 1.

The sample was subdivided into a 6 × 5.7-mm group (n = 45) and a non–6 × 5.7-mm group (n = 127). Table 2 summarizes the bivariate relationships between 6 × 5.7-mm and non–6 × 5.7-mm implants and the various study variables. The mean age at implant placement was 55.8 ± 11.1 years for 6 × 5.7-mm implants and 60.4 ± 12.1 years for non–6 × 5.7-mm implants. The associated *P* value of 0.34 shows that a significant difference did not exist between the 2 groups in regard to the mean age at implant placement. Twenty-seven (60.0%) of the 45 6 × 5.7-mm implants were placed in men, while 51.2% of the non–6 × 5.7-mm implants were placed in men ($P = .63$).

The bivariate analyses did identify several variables for possible inclusion in a multivariate model ($P \leq .15$), including ASA type, the presence of a medically compromising condition, jaw location (mandible or maxilla) and staging, and the use of a reconstructive procedure to enhance the recipient site.

Table 3 summarizes the Kaplan-Meier survival analyses adjusted for clustered observations. There were 12 failures overall, with 3 occurring in 6 × 5.7-mm implants and 9 occurring in non–6 × 5.7-mm implants. Given the relatively short duration of follow-up for most of the 6 × 5.7 mm implants (24.5 months, versus 31.8 months for non–6 × 5.7-mm implants), the survival analyses were limited to 1 year. The 1-year survival rates (with associated CIs) were 92.2% ± 2% (83.6 to 100.0) for 6 × 5.7-mm implants, 95.2% ± 2% (91.1 to 99.3) for non–6 × 5.7-

Table 1 Descriptive Statistics

	Implants		Patients	
	k	%	n	%
Gender				
Male	92	53.5	20	57.1
Female	80	46.5	15	42.9
Health status variables				
ASA status				
ASA I	65	37.8	18	51.4
ASA II	75	43.6	13	37.1
ASA III	32	18.6	4	11.4
Medically compromised				
Yes	48	27.9	7	20.0
No	124	72.1	28	80.0
Tobacco use*				
Yes	0	0.0	0	0.0
No	164	100.0	33	100.0
Anatomic variables				
Jaw				
Anterior Maxilla	30	17.4		
Anterior Mandible	8	4.7		
Posterior Maxilla	59	34.3		
Posterior Mandible	75	43.6		
Implant proximity				
No teeth	5	2.9		
1 adjacent tooth	13	7.6		
2 natural teeth	28	16.3		
1 adjacent implant	39	22.7		
2 adjacent implants	38	22.1		
1 tooth + 1 implant	49	28.5		
Bone quality (n = 118)				
Type 1	0	0.0		
Type 2	26	22.0		
Type 3	36	30.5		
Type 4	56	47.5		
Implant-specific variables				
Diameter (k = 169)				
3.0 mm	1	0.6		
3.5 mm	27	16.0		
4.0 mm	33	19.5		
4.5 mm	28	16.6		
5.0 mm	32	18.9		
6.0 mm	48	28.4		
Length (k = 165)				
5.7 to 6.0 mm	45	27.3		
8.0 mm	55	33.3		
11.0 mm	62	37.6		
14.0 mm	3	1.8		
Coating (k = 162)				
Uncoated	28	17.3		
TPS	50	30.9		
HA	84	51.9		
Well size (k = 104)				
2 mm	9	8.7		
3 mm	95	91.4		
Staging (k = 171)				
1-stage	68	39.8		
2-stage	103	60.2		
Immediate implant				
Yes	35	20.4		
No	137	79.6		
6 × 5.7				
Yes	45	26.2		
No	127	73.8		
Prosthesis variables				
Crown	154	92.8		
Fixed prosthesis	11	6.6		
Removable or overdenture	1	0.6		
Peri-operative variables				
Antibiotic use (k = 171)				
Yes	153	89.5		
No	18	10.5		
Reconstructive variables				
Yes	31	18.0		
No	141	82.0		

Information presented for 35 patients and 172 implants unless otherwise noted.
*Data presenteded for 164 implants and 33 patients.

Table 2 Study Variables Stratified By Implant Size

	6 × 5.7-mm		Non–6 × 5.7-mm		
	k	%	k	%	*P*
No. of implants	45	26.2	127	73.8	NA
Demographic variables					
Gender of patient					
Male	27	60.0	65	51.2	.63
Female	18	40.0	62	48.8	
Health status variables					
ASA status					
ASA I–II	38	84.4	102	80.3	.15
ASA III–IV	7	15.6	25	19.7	
Medically compromised					
Yes	10	22.2	38	29.9	.15
No	35	77.8	89	70.1	
Tobacco use*					
Yes	0	0.0	0	0.0	
No	42	100.0	122	100.0	NA
Anatomic variables					
Jaw					
Maxilla	11	24.4	76	59.8	.08
Mandible	34	75.6	51	40.2	
Anterior Maxilla	0	0.0	30	23.6	
Anterior Mandible	1	2.3	7	5.5	
Posterior Maxilla	11	24.4	48	37.8	
Posterior Mandible	33	73.3	42	33.1	
Implant proximity					
No teeth	2	4.4	3	2.4	.99
1 adjacent tooth	9	20.0	4	3.2	
2 natural teeth	10	22.2	18	14.2	
1 adjacent implant	12	26.7	27	21.3	
2 adjacent implants	4	8.9	34	26.8	
1 tooth + 1 implant	8	17.8	41	32.3	
Bone quality*					
Type 1	0	0.0	0	0.0	.53
Type 2	9	24.3	17	21.0	
Type 3	14	37.8	22	27.1	
Type 4	14	37.8	42	51.9	
Implant specific variables					
Coating*					
Uncoated	19	42.2	9	7.7	.89
TPS	11	24.4	39	33.3	.37
HA	15	33.3	69	59.0	.33
Staging*					
1-stage	19	42.2	49	38.9	.09
2-stage	26	57.8	77	61.1	
Immediate implant†					
Yes	7	15.6	28	22.1	.99
No	38	84.4	99	77.9	
Prosthesis variables*					
Crown	42	97.7	112	91.1	
Fixed prosthesis	1	2.3	10	8.1	
Removable or overdenture	0	0.0	1	0.8	.99
Peri-operative variables*					
Antibiotic use					
Yes	40	88.9	113	89.7	.98
No	5	11.1	13	10.3	
Reconstructive procedures					
Yes	4	8.9	27	21.3	.08
No	41	91.1	100	78.7	

Information presented for 35 patients and 172 implants unless otherwise noted.
*Some values are missing.
†Data for 45 patients shown.
NA = not applicable.

Table 3 Survival Time (mo) of 6 × 5.7-mm Implants vs Non–6 × 5.7-mm implants

Time	No. of 6 × 5.7-mm implants at risk	Survival (%)	No. of non–6 × 5.7-mm implants at risk	Survival (%)	*P*
0	45	100	124	100	NA
12	31	92.2 ± 4	87	95.2 ± 2	.78
24	16	92.2 ± 4	83	94.1 ± 2	NA
36	12	92.2 ± 4	39	92.4 ± 3	NA
48	7	92.2 ± 4	29	92.4 ± 3	NA
60	3	92.2 ± 4	19	92.4 ± 3	NA

NA = not applicable.

Table 4 Bivariate Analysis for Risk Factors Associated with Implant Failure for All Patients and Implants

	Hazard ratio	95% CI	*P*
Demographic variables			
Age at implant placement	1.0	0.9–1.0	.40
Female gender	1.1	0.4–3.5	.80
Health status variables			
ASA status (n = 35)	0.6	0.2–1.3	.20
Medically compromised	0.2	0.0–1.6	.13
Anatomic variables			
Posterior location	0.8	0.2–2.9	.70
Mandibular position	0.5	0.1–1.6	.20
Implant proximity	1.0	0.7–1.5	> .99
Bone quality	1.4	0.5–3.7	.50
Implant-specific variables			
Diameter	1.1	0.6–2.1	.70
Length	0.9	0.7–1.1	.30
Coating			
TPS	0.6	0.0–4.3	.60
HA	1.6	0.3–7.7	.60
Well size	0.6	0.1–4.6	.60
Staging (2-stage)	0.4	0.1–1.3	.12
Size (6 × 5.7 vs non–6 × 5.7)	1.2	0.3–4.8	.80
Peri-operative variables			
Antibiotic use	1.1	0.1–8.5	.90
Reconstructive variables			
Bone graft augmentation	2.5	0.8–8.6	.13

Table 5 Multivariate Marginal Cox Regression Model For All Patients and Implants

	Hazard ratio	95% CI	*P*
Major predictor variable			
Size (6 × 5.7 vs non–6 × 5.7)	1.0	0.3–4.3	.95
Demographic variables			
Age at implant placement	1.0	0.9–1.0	.14
Female gender	1.1	0.3–4.3	.92
Health status variables			
Medically compromised	0.4	0.0–4.2	.46
Implant-specific variables			
Staging (2-stage)	0.2	0.04–1.03	0.055
Reconstructive variables			
Bone graft augmentation	2.6	0.6–12.1	.23

mm implants, and 93.9% ± 2% (89.9 to 97.8) for the combined groups. The difference in 1-year survival between the 6 × 5.7-mm and non–6 × 5.7-mm implants was not statistically significant ($P = .78$).

The associations between the predictor variables and implant failure are summarized in Table 4. While none of the variables were statistically associated with implant failure, several variables were considered for inclusion in the study model based on screening criteria established at the beginning of the study, ie, $P \leq .15$. The variables that were near statistically significant were the presence of a medically compromising disease, staging, and use of reconstructive procedures.

The results of the multivariate model are summarized in Table 5. The primary predictor variable was implant size. The primary outcome was implant survival. The other variables included in the model were considered biologically important (ie, age and sex) or were potential confounders (ie, health status, staging, and reconstructive procedures). This multivariate model found staging to be closely statistically associated with implant failure. The hazard ratio for staging was 0.2 with an associated 95% CI of 0.04 to 1.03 ($P = .055$). This is interpreted as meaning that 2-stage implants are 80% less likely to fail than implants placed in a single stage.

DISCUSSION

Implant selection is generally based on the maximum amount of available bone. This logic is based on the principle that favorable load distributions exist when the greatest surface area of bone is contacted by the implant to facilitate the transfer of

occlusal forces.[36] In the presence of limited alveolar bone height, the use of longer implants may not be an option. The aims of this study were to estimate the 1-year survival of 6 × 5.7-mm Bicon implants, to compare the survival of 6 × 5.7-mm implants to non–6 × 5.7-mm implants, and to identify risk factors for failure associated with this system.

The overall 1-year survival estimate for Bicon implants in this cohort was 93.9%. The survival rates for 6 × 5.7-mm implants and non–6 × 5.7-mm implants were 92.2% and 95.2%, respectively (P = .78). These results are consistent with the findings of Vehemente and colleagues.[37] In their study of the Bicon implant system, the 1-year and 5-year survival rates were found to be 95.2% and 90.2%, respectively.

The comparable survival estimates for 6 × 5.7 mm and non–6 × 5.7-mm implants in this study suggest that 6 × 5.7-mm implants can integrate and bear a functional load after placement. Indeed, data regarding short implants has become increasingly positive over the past few years. A 1998 study by ten Bruggenkate and associates reported a 6-year survival rate of 94% for 6-mm-long Straumann implants (Institut Straumann, Waldenburg, Switzerland).[17] Similarly, Friberg and coworkers[18] found the 5-year survival rate to be 95.5% for a cohort of short Brånemark System implants (Nobel Biocare, Göteborg, Sweden) and Davarpanah and colleagues[19] found a success rate at 3 years of short Osseotite implants (3i/Implant Innovations, Palm Beach Gardens, FL) of 98.4%. These recent studies confirm the results presented in this study and offer a gauge for the future performance of short implants.

There are distinct differences, however, between this study and the aforementioned trials. It is important to first discuss the definition of "short" and its implications in these studies. Most studies regard a short length as being ≤ 10 mm, with a majority of implants being either 7 mm or 10 mm long.[20] Very few studies involve implants with lengths of 6 mm.

Diameter is another variable that differs from study to study. In 1990, Matsushita and colleagues[28] recommended increasing implant diameter to compensate for decreases in length. While Bahat and Handelsman[30] and Scurria and coworkers[31] reported favorable results with wide implants, Eckert and colleagues[38] reported 1-year survival estimates of 64.9% in the maxilla and 75.1% in the mandible for the Wide Platform MK II implant (Nobel Biocare).[38] Similarly, Ivanoff and associates[39] reported a significantly higher failure rate with a 5-mm-wide implant. In the authors' review of the literature, few studies that combined short lengths with large diameters were found.[18–21] Thus, this may be the first study reporting clinical outcomes of a 6 × 5.7-mm implant.

Type of prostheses also varies from study to study. Interestingly, a majority of the studies reporting poor survival of short implants mentioned little about the definitive restoration.[5–10,12,13] Others reported the use of short implants for supporting overdentures.[11,14–16] Even ten Bruggenkate and colleagues[17] reported favorable clinical results for a 6-mm-long implant and recommended using short implants in combination with longer implants. In the present study, 92.8% of all implants studied with prosthetic restorations and 97.7% of 6 × 5.7-mm implants were restored with single crowns. Success in this situation may lead to acceptance of the 6 × 5.7-mm implant as a viable alternative for the prosthetic replacement of a single tooth.

Of note, a majority of the 6 × 5.7-mm implants in this study were placed in type 3 and type 4 bone. Many studies have regarded bone quality as a significant risk factor for failure.[9,11,40–42] In fact, a 1991 study by Jaffin and Berman[43] recommended the presurgical determination of type 4 bone as 1 method to decrease implant failure. Only one of the three 6 × 5.7-mm implants that failed in this study were placed in poorer-quality bone. These preliminary results may indicate that 6 × 5.7-mm implants are useful in the restoration of areas with poor bone quality.

The 2 largest limitations of this study involve the small sample size and relatively short duration of follow-up (less than 5 years) for most patients. It should be noted that 7 of the 6 × 5.7-mm implants survived beyond 4 years. In addition, 16 of 45 were surviving with prostheses in place and 25 of 45 had integrated without prostheses in place. The 3 failures in the 6 × 5.7-mm group all occurred prior to loading and were therefore categorized as early failures. Prospective follow-up studies with longer follow-up times and larger sample sizes are necessary to validate the current findings.

In the present analysis of the risk factors for implant failure, variables were selected that were biologically important (age and gender) or were potential confounders defined as being associated with both the predictor and outcome variables with $P \leq .15$. For this cohort of implants, 3 variables—having a medically compromising disease, staging, and dentoalveolar reconstructive procedures—were deemed as sufficient for inclusion in a multivariate model. When controlling for size, age, gender, a medically compromising condition, and dentoalveolar reconstruction, staging was found to be statistically associated with implant failure (P = .049). This finding is consistent with the results of Vehemente and colleagues[37] and the idea that 2-stage surgery allows osseointegration to proceed in a favorable environment without exposure to destructive forces.

CONCLUSIONS

This may be the first study reporting on clinical outcomes of the Bicon 6 × 5.7-mm implant. The survival rate of 6 × 5.7-mm implants was comparable to that of non–6 × 5.7-mm implants. These data support the hypothesis that 6 × 5.7-mm implants can be a clinically acceptable option to facilitate prosthetic restoration where alveolar bone height is limited or anatomic limitations exist. In addition, the results suggest that a 2-stage approach is associated with 80% less failure than a 1-stage approach when placing these implants.

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