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A Screwless and Cementless Technique for the Restoration of Single-tooth Implants: A Retrospective Cohort Study

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Abstract

Purpose: The Integrated Abutment Crown™ (IAC) is a technique for the fabrication of single-tooth implant-supported crowns where the abutment and the crown are one unit. The abutment–crown complex is connected to the implant with a locking taper. This technique does not use cement to retain the crown or screws to retain the abutment. The purpose of this study was to evaluate the clinical outcome of screwless, cementless single implant-supported crowns (IACs) placed in a general dental practice.
Materials and Methods: A retrospective cohort study was conducted between July 2001 and August 2003. Patients were recalled between January and March 2004. The restorations were evaluated following the modified United States Public Health Service (USPHS) criteria. Several other variables, such as anatomic form, occlusion, soft tissue health, and reconstructive procedures, were also recorded. Descriptive statistics, univariate and multivariate marginal Cox Proportional Hazards Regression models, adjusted for multiple implants in the same patient, were used.
Results: During the chart review, 108 patients were identified. A cohort of 59 patients with a total of 151 IACs met the inclusion criteria. The Kaplan–Meier survival rate for IACs was 98.7%. Two IACs were removed, one due to implant failure; the other became loose several times and was replaced with a splinted restoration. Excellent marginal adaptation was observed with no clinically discernible interface between the veneer material and the abutment. Nine maxillary anterior IACs loosened on five patients; eight of them were reinserted and continued in function without further problems for the remainder of the study. An IAC located between a tooth and an implant was 2.65 times more likely to have postinsertion complications ($p = 0.05$). An IAC with incorrect anatomic form (overcontoured) was 3.26 times more likely to have postinsertion complications ($p = 0.01$). Maxillary anterior IACs adjacent to one tooth and one implant were 3.9 times more likely to come loose ($p = 0.05$).
Conclusions: The clinical outcome of this screwless and cementless system for single implant restorations compares favorably with the experience of screw- and cement-retained single implant restorations within the observation period.

Common techniques to achieve structural integrity of the crown/abutment and implant/abutment complexes in single-tooth implant restorations include screws and cement.[1-16]

When both the implant–abutment and crown–abutment complexes are retained with screws, long-term follow-up studies have reported several complications, including screw loosening, fracture, and other component failures.[1-7] Screw loosening appears to be a greater problem with single-tooth restorations replacing mandibular molars.[1,6,8,9] With regard to sulcular health, a screw-retained prosthesis does not seal the abutment-to-crown interface or margin, which harbors bacteria in the crevice. This may act as an endotoxin pump, encouraging the proliferation of micro-organisms in the sulcular region.[10-12]

When a crown is cemented onto an implant abutment, it is possible for excess cement to flow into the gingival sulcus.[13,14] Subgingival margins make it difficult to ensure the complete removal of excess cement,[14-16] and the possibility exists for residual cement to be forced into the sulcus as the restoration

Figure 1 Insertion of an IAC. Both maxillary central incisors are IACs. A restoration is being inserted (A). Lateral view of the crowns after insertion (B). Periapical radiograph (C). (Picture courtesy Dr. Vincent Morgan, Implant Dentistry Centre, Boston, MA.)

is being seated.[13,14,16] Incomplete cement removal from the gingival sulcus can lead to loss of peri-implant bone that may be visualized radiographically.[13,14] Furthermore, a gap between the crown and the implant or abutment has been associated with greater marginal bone loss during the first year of function.[5]

The Bicon Dental Implant™ system (Bicon, LLC., Boston, MA) is a screwless implant system. The implant and implant–abutment unit connect by means of a 3.0° locking taper. The high friction force created by the locking taper breaks down the titanium oxide layer, and the metals are fused together in a cold weld.[17] Therefore, there are no gaps between the implant and the abutment. The locking-taper connection provides a frictional seal shown to be hermetic to bacterial invasion[18] and clinically reliable.[19] A 10-year survival rate of 99.0% for Bicon implants restored with single-tooth restorations has been documented.[20]

The Integrated Abutment Crown™ (IAC) (Bicon, LLC.) is an implant restoration where the implant abutment and the crown material are one unit[21] (Fig 1). A light-cured, highly filled composite resin material, such as Diamond Crown™ (DRM Research Laboratories, Branford, CT), is chemo-mechanically bonded in the laboratory to the coronal part of a titanium alloy abutment. This technique does not require cement or screws.

The purpose of this study was to examine the clinical outcome of single implant-supported IACs placed in a general practice and to create a basis for further long-term evaluation of this type of restoration. The hypothesis was that the screwless and cementless implant restoration presented in this study should have comparable performance to screw- and cement-retained single implant restorations.

Materials and methods

The present study was designed as a retrospective cohort study. The cohort was derived from the population of patients who had at least one IAC restored at the Implant Dentistry Centre, Faulkner Hospital (IDC-FH), Boston, MA between July 2001 and August 2003.

Patients of record treated at IDC-FH were selected if they satisfied the following inclusion criteria: (i) restored with at least one IAC and (ii) consented to participate after being fully informed of the conditions of the study. Exclusion criteria included inadequate or unavailable patient charts and/or patient unwilling or unable to attend the follow-up examination.

This study was approved by the Faulkner Hospital Institutional Review Board, Boston, MA.

This retrospective study involved the examination of patient records as well as clinical evaluations of the restorations during recall appointments between January and March 2004. Periapical and panoramic radiographs and clinical photographs were obtained.

Study variables

Health status variables

Demographic variables included age and gender. General health status was classified according to the American Society of Anesthesiology (ASA) system.[22] Patients were categorized as healthy (ASA 1), as having mild systemic disease (ASA 2), or as having moderate or severe systemic disease (ASA 3). Past history of smoking as well as current tobacco and alcohol use were documented.

Anatomic-tooth specific variables

These variables included implant position (maxilla, mandible, anterior, posterior), tooth type (incisor, canine, premolar, molar), bone quality (types 1-4), and proximity of the implant relative to other teeth or implants. The proximity of implants to other dento-alveolar structures were grouped into the following categories: no teeth (edentulous), one natural tooth, two natural teeth, one implant, two implants, and one natural tooth-one implant.[23] The presence of endodontic treatment of the teeth immediately adjacent to the implant areas and the reasons for tooth loss were recorded.

Implant-specific variables

These variables included size (width 3.5 to 6 mm, length 6 to 11 mm), coating [uncoated, titanium-plasma sprayed (TPS), hydroxyapatite (HA)], well size (2 or 3 mm), and surgical protocol (one vs. two stage). Immediate extraction and placement was recorded when a tooth was extracted on the same

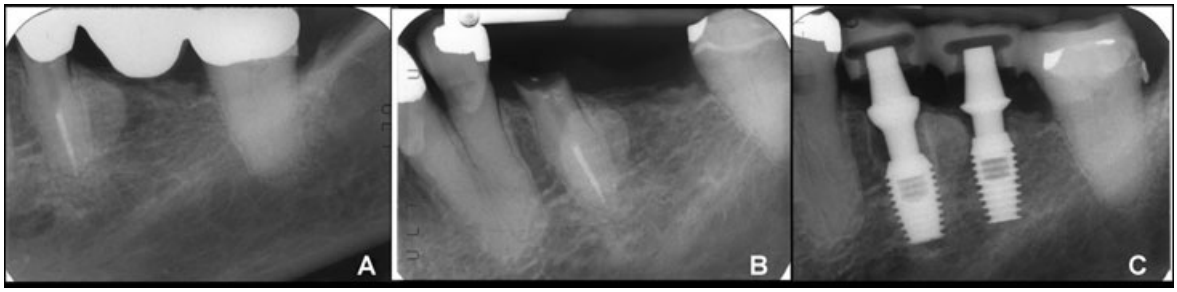

Figure 2 Periapical radiographs of a mandibular left bicuspid and first molar area, before treatment (A), after removal of the failing fixed partial denture (B), and after implant placement (C). The second mandibular left bicuspid was extracted, and an implant was placed on the same day. Implants on second premolar and first molar were splinted to adjacent teeth with composite resin and placed in occlusion on the day of implant placement (C).

day as implant placement. When the implant restoration was placed in occlusion and splinted to adjacent structures on the same day of implant placement, it was recorded as immediate loading/stabilization (Fig 2).

Reconstructive variables

Bone graft augmentation procedures prior, at, or after implant placement were recorded.

Prosthetic-soft tissue variables

Stability of the implant and crown–abutment complex was determined by tapping back and forth between two instrument handles. Fractures and interproximal and occlusal contacts were documented. Fractures were defined as loss of core material, regardless of the amount and/or presence of cracks or fracture lines. Occlusal contacts were verified by the presence of marks and resistance to dislodgement of articulating paper (0.04-mm thick, Bausch articulating papers, Nashua, NH) when the patient's occlusion was in maximal intercuspation. A positive interproximal contact was recorded when resistance to dental floss and the presence of contact upon visual evaluation was observed.

Contact between opposing teeth on both right and left working sides during excursive jaw movements (lateral guidance) was documented as canine protected articulation or group function.[24] The contacts were verified twice by the presence of marks and resistance to dislodgement of articulating paper.

Occlusion was classified on both right and left sides as class I, II, or III according to Angle's classification of occlusion.[24] If an IAC was located on the maxillary or mandibular right side, the type of occlusion and lateral guidance present on that side were recorded for that restoration. If an IAC had a positive working side contact, the restoration was recorded as guiding excursion. Furthermore, the structure of the opposing occlusal contact [tooth, implant, implant overdenture, removable partial denture (RPD), or complete denture (CD)] and the type of restorative material present on the opposing supporting cusp (tooth structure, porcelain, metal, acrylic, composite resin) were documented.

Using the modified United States Public Health Service (USPHS)[25] criteria, the crowns were evaluated for color match, surface texture, marginal adaptation, and anatomic form. Values of 0 (alpha) and 1 (bravo) were considered clinically acceptable. Values of 2 or higher required further treatment. For color match, an unrestored tooth in close proximity served as the comparison.

A restoration was considered an absolute failure when it could not remain in function as a consequence of implant loss or prosthetic malfunction.

Three soft tissue parameters were recorded for each implant site. The modified plaque index[26] and sulcular bleeding index[27] were recorded on the facial surfaces, and sulcular depth measurements were obtained on six surfaces (ml, l, dl, mf, f, df). A prosthodontist (first author) obtained the clinical measurements. To ensure consistency, several trial examinations were performed prior to the actual clinical measurements being recorded.

Complications

Prosthodontic, surgical, or other complaints and all complications were noted.

Patient questionnaire

The patients' perceptions of esthetic results, satisfaction, and comfort were obtained using a standard questionnaire.[4] The survey was mailed to the patients after clinical evaluation had already been performed.

Data management and statistics

A database was created using Excel (Microsoft 2000, Seattle, WA) with appropriate checks to identify errors. Descriptive statistics were computed for all the study's variables. Univariate analyses were used to identify risk factors associated with complications after insertion of the IACs. Prosthetic risk factors with p-values ≤ 0.15 based on univariate analyses were entered into multivariate Cox proportional hazards regression models that adjusted for clustering failure-time observations within the same patient using the marginal approach.[28] Crown (IAC) survival rate was computed using the Kaplan–Meier

Estimator.[29] Survival statistical computing methodologies used the SAS (Version 8.2, Cary, NC) programming environment in the PC-DOS operating system. The procedure code "proc phreg" in SAS with the "covsandwich" or "covs" option was used.

Results

A total of 108 patients were restored with 285 IACs between July 2001 and August 2003. All records of the 108 patients were reviewed. Among the 108 patients, 59 patients had subsequent follow-up visits and were included in the present study.

The cohort was composed of 151 Bicon implants restored with IACs on 59 patients with a mean age of 57.2 ± 14.3 years. Women made up 57.6% of the studied group.

The average time the IACs were in function was 16.7 months. The descriptive statistics for the study variables are summarized in Table 1.

The reason for tooth loss prior to implant placement was not available for 55 teeth. Of the remaining 96 teeth, 30 teeth (31.3%) were lost because of fractures or trauma, 42 teeth (43.8%) were extracted because of advanced dental caries, and 21 teeth (21.9%) were removed because of periodontal and/or endodontic reasons.

Two failures were documented. One IAC replacing a maxillary left second premolar was removed 1 month after insertion of the definitive restoration, due to the failure of the implant to become osseointegrated. The failed implant had been splinted to a previously integrated implant and placed in function with a temporary restoration immediately after placement. The implant was removed because of mobility and pain. An IAC replacing a maxillary lateral incisor was removed because it became loose several times. The new restoration was splinted to an adjacent implant to prevent further dislodgement. One hundred forty-nine IACs were in function at the last recall appointment and were classified as excellent for anatomic form (75.8%), marginal adaptation (98%), color match (64.1%), and surface texture (68.5%).

Fifty-one IACs had supragingival plaque recognizable with a periodontal probe (score 1, modified plaque index.[26]

The Kaplan–Meier[29] survival estimate for IACs was 98.7% with an associated 95% confidence interval between 96.8% and 100% (Table 2).

The patients' responses to their treatments were positive (Table 3). The majority of patients (95.7%) were extremely satisfied (score 0). Twelve patients did not return their questionnaire but were contacted by phone and reported having no problems.

In addition to the implant failure, the following complications were noted after insertion of the IACs, all of which occurred in the maxilla. A small fracture of the core material was documented on a maxillary left first premolar during the first year of function. After refinishing, the crown continued in function uneventfully for the remainder of the study. One patient complained of throbbing pain due to soft-tissue irritation around an IAC that had been in function for 1 year. Four occlusal contacts were adjusted due to biting sensitivity. An interproximal contact was added to an anterior IAC that had been in function for 5 months. Loosening of nine maxillary anterior IACs was documented.

The majority of the postinsertion complications occurred in restorations opposing natural teeth (16 out of 17, or 94%), immediately loaded implants (10 of 17, or 59%), and restorations adjacent to one tooth-one implant (10 of 17, or 59%).

Of the IACs that loosened, nine (100%) were opposing natural teeth, six (66%) were adjacent to one tooth-one implant, three (33%) were adjacent to two implants, and five (56%) implants had been immediately loaded. Of the eight IACs that loosened but remained in function, three (38%) had incorrect anatomic form and four (50%) lacked occlusal contacts.

Table 1 summarizes the univariate relationships between the study variables and complications after insertion of the IACs. During the univariate analysis, the following variables were identified as risk factors ($p \leq 0.15$) for complications after insertion of the IACs: adjacent structures, surgical protocol, immediate loading/stabilization, occlusal contacts, type of opposing structure, color match, anatomic form, and modified plaque index. Two clustered parsimonious multivariate regression models were developed (Table 4).Variables in the multivariate models were selected because they were statistically associated with complications in univariate analysis ($p \leq 0.15$) and were of prosthetic relevance. In the multivariate Cox models shown in Table 4, anatomic form, IAC adjacent to one tooth and one implant, and occlusal contacts remained statistically associated with complications after insertion of the IACs ($p \leq 0.05$). If an IAC had incorrect anatomic form, it was 3.26 times more likely to develop complications after insertion ($p = 0.01$; Table 4A). If an IAC was located between an implant and a tooth, it was 2.65 times more likely to have complications after insertion ($p = 0.05$; Table 4A). An IAC without contact in maximal intercuspation was 2.53 times more likely to have postinsertion complications ($p = 0.05$; Table 4B). Immediately stabilized implants were more likely to have postinsertion complications but not at a statistically significant level ($p = 0.08$; Table 4B).

To further evaluate the possible relationships of these risk factors with loosening of maxillary anterior IACs, a subgroup statistical analysis was performed. Maxillary anterior IACs adjacent to one tooth and one implant were 3.9 times more likely to come loose ($p = 0.05$).

Discussion

The most common materials used for the restoration of both teeth and implants are ceramo-metal and all-ceramic crowns. According to Paul and Pietrobon[30] in their literature review, a single implant-retained metal–ceramic crown cemented on a metal abutment may be considered the standard selection.

The implant restorations evaluated in this study differ from cemented metal–ceramic crowns in that the metal abutments and the crown material were chemo-mechanically bonded in the laboratory; therefore, there was no need for cement. Also, the abutments were connected to the implants with a screwless locking taper, another significant difference. The concept of incorporating a screwless, locking taper implant abutment with a crown material in a single integrated unit is new.

Table 1 Descriptive statistics and univariate analysis for risk factors associated with complications after insertion of the IACs (total n = 59 patients; total k = 151 implants)

Variable	Number	Percent	HR (95% CI)	Robust *p*-value
Age at implant placement (n = 59)	57.2 ± 14.3 (range 27.8-90.8)		0.98 (0.95, 1.01)	0.22
Gender (n = 59)				
Female	34	57.6	0.50 (0.19, 1.35)	0.17
Male	25	42.4	1.00 (Ref.)	
ASA status (n = 59)			1.09 (0.54, 2.22)†	0.80
ASA I	54	91.5		
ASA II	4	6.8		
ASA III	1	1.7		
Tobacco use (n = 59)				
Yes	7	11.9	0.73 (0.21, 2.52)	
No	52	88.1	1.00 (Ref.)	0.62
Jaw (k = 151)				
Mandible	57	37.8	‡	<0.0001*
Maxilla	94	62.3	1.00 (Ref.)	
Tooth type (k = 151)				
Incisor	34	22.5	7.46 (1.64, 33.92)	0.009
Canine	10	6.6	1.90 (0.18, 20.03)	0.59
Premolar	67	44.4	1.18 (0.22, 6.42)	0.85
Molar	40	26.5	1.00 (Ref.)	
Bone quality (k = 109)				
Type II	15	13.8	1.89 (0.73, 4.87)†	0.19
Type III	20	18.4		
Type IV	74	67.9		
Adjacent structures (k = 151)				
Adjacent to 1 tooth + 1 implant	63	41.7	2.25 (0.86, 5.92)	0.10
Not adjacent to 1 tooth + 1 implant	88	58.3	1.00 (Ref.)	
Diameter (k = 151)				
3.5 mm	16	10.6	0.88 (0.53, 1.47)†	0.63
4 mm	29	19.2		
4.5 mm	45	29.8		
5 mm	51	33.8		
6 mm	10	6.6		
Length (k = 151)				
6 mm	7	4.6	1.13 (0.85, 1.51)†	0.39
8 mm	85	56.3		
11 mm	59	39.1		
Coating (k = 151)				
Uncoated	5	3.3	2.00 (0.26, 15.35)	0.50
TPS	32	21.2	1.15 (0.36, 3.74)	0.81
HA	114	75.5	1.00 (Ref.)	
Surgical protocol (k = 151)				
2 stage	52	34.4	0.39 (0.11, 1.35)	0.14
1 stage	99	65.6	1.00 (Ref.)	
Immediate extraction (k = 151)				
Yes	47	31.1	1.69 (0.65, 4.38)	0.28
No	104	68.9	1.00 (Ref.)	
Immediate loading/stabilization (k = 151)				
Yes	55	36.4	2.94 (1.10, 7.89)	0.03
No	96	63.6	1.00 (Ref.)	
Bone augmentation before implant (k = 151)				
Yes	7	4.6	‡	<0.0001*
No	144	95.4	1.00 (Ref.)	
Bone augmentation at implant (k = 151)				
Yes	47	31.1	0.66 (0.21, 2.05)	0.47
No	104	68.9	1.00 (Ref.)	

Continued

Table 1 Continued

Variable	Number	Percent	HR (95% CI)	Robust *p*-value
Interproximal contacts (k = 149)				
Yes	116	77.9	0.83 (0.27, 2.59)	0.75
No	33	22.1	1.00 (Ref.)	
Occlusal contacts (k = 149)				
Yes	116	77.9	1.00 (Ref.)	
No	33	22.1	3.02 (1.11, 8.17)	0.03
Type of occlusion (angle) (k = 151)				
Class III	16	10.6	2.01 (0.41, 9.76)	0.39
Class II	48	31.8	1.51 (0.53, 4.31)	0.44
Class I	87	57.6	1.00 (Ref.)	
Lateral guidance (k = 151)				
No contact due to balancing interferences	2	1.3	‡	<0.0001
Group function	86	57.0	1.14 (0.43, 3.04)	0.79
Canine	63	41.7	1.00 (Ref.)	
IAC guiding excursion (k = 149)				
Yes	30	20.1	0.59 (0.14, 2.60)	0.49
No	119	80.0	1.00 (Ref.)	
Type of opposing structure (k = 151)				
None	3	2.0	‡	<0.0001
Tooth	107	70.9	1.00 (Ref.)	
Implant	37	24.5	0.15 (0.02, 1.17)	0.07
RPD/CD implant-supported	4	2.7	‡	<0.0001
Type of opposing material (k = 151)				
None	3	2.0	Not compared	
Tooth structure	66	43.7	1.000 (Ref.)	
Porcelain	44	29.1	0.45 (0.14, 1.39)	0.16
Metal	6	4.0	Not compared	
Acrylic/IPN	5	3.3	Not compared	
DC resin	27	17.9	‡	<0.0001
USPHS criteria (k = 149)				
Color match				
0-excellent match	91	64.1	2.32 (0.84, 6.45)†	0.11
1-minimal mismatch	51	35.9		
Surface texture				
0-smooth	102	68.5	0.50 (0.15, 1.69)†	0.27
1-dull	46	30.9		
2-rough, pitted	1	0.7		
Marginal adaptation				
0-no catch	146	98.0	1.000 (Ref.)	
1-catch	3	2.0	†,‡	< 0.0001*
Anatomic form				
0-correct	113	75.8	2.94 (1.28, 6.75)†	< 0.011
1-incorrect	35	23.5		
2-defective	1	0.7		
Mean modified plaque index	0.5 ± 0.6 (range 0-2)		0.45 (0.18, 1.15)	0.10
Mean sulcular bleeding index	0.2 ± 0.4 (range 0-2)		0.27 (0.04, 1.95)	0.19
Mean sulcular depth (mm)	3.0 ± 0.7 (range 1.5-5.0)		0.88 (0.44, 1.79)	0.72
Presence of complications (k = 151)				
No	134	88.7		
Yes	17	11.3		

*All complications occurred: in the maxilla, in patients with no augmentation procedures done before implant placement, and in restorations with good marginal adaptation.

†Modeled as a continuous variable with the HR for a linear trend.

‡HR was undetermined because there were no complications for this level of the covariate.

Note: Ref. means the "reference group" at each level of the covariate. The HR (hazard ratio) for the reference group is set at 1.00.

Table 2 Kaplan–Meier survival for integrated abutment crowns

Time after insertion (months)	n (at risk)	%	95% CI	K (failed)
0	151	100	100	0
6	113	98.7	96.8, 100.0	2
12	101	98.7	96.8, 100.0	0
18	61	98.7	96.8, 100.0	0
24	21	98.7	96.8, 100.0	0

The IACs showed a 98.7% survival rate during a period of observation of up to 29 months with 71% of them restoring posterior areas.

These results compare favorably with the 12-18 month cumulative survival rate of 98.2% reported by Naert et al.[31] In a 5-year study with a lower cumulative success rate of 93.7% for implant-supported single crowns, two fractures of all-ceramic restorations were reported in the first 2 years where the majority of the crowns (79%) evaluated were placed in anterior areas.[32] Another study of implant-supported single-tooth replacements reported five fractured crowns during a period of up to 8 years where the majority of the restorations (31 of 49) were placed in anterior areas and the majority of the fractures (4 out of 5) occurred in posterior areas.[33]

Excellent marginal adaptation was observed with no clinically discernible interface between the veneer material and the implant abutment for 98% of the IACs. Even though the marginal adaptation showed no deterioration over time (Figs 3 and 4), the stability of the bond between the metal abutment and the resin veneering material will need to be demonstrated in long-term studies.

The surface texture rating was reduced in 47 IACs because of a slightly dull or granular surface appearance. Past research has shown that when polished, resin materials achieve higher roughness values than all-ceramic materials.[34]

Table 3 Descriptive statistics for patient questionnaire (score 0-5) (n = 47 patients)

	Number	Percent
Satisfaction with implant crown		
0—extremely satisfied	45	95.7
1—somewhat satisfied	2	4.3
Satisfaction with appearance		
0—extremely satisfied	40	85.1
1—somewhat satisfied	3	6.4
2—no feeling either way	4	8.5
Would select same type of crown		
0—extremely satisfied	37	78.7
1—somewhat satisfied	8	17.0
2—no feeling	2	4.3
Would recommend procedure to a friend		
0—extremely satisfied	39	83.0
1—somewhat satisfied	7	15.0
2—no feeling	1	2.1
Appearance compared to teeth		
0—extremely satisfied	13	27.7
1—somewhat satisfied	16	34.0
2—no feeling	18	38.3

Table 4 Multivariate marginal Cox regression models for risk factors associated with complications after insertion of IACs (total N = 59 patients; total k = 151 implants)

Variable	Hazard ratio	95 % CI	Robust *p*-value
A. First multivariate model			
Adjacent to one tooth-one implant	2.65	(1.00, 7.15)	0.05*
Not adjacent to one tooth-one implant	1.00 (Ref.)		
USPHS, anatomic form	3.26	1.32, 8.07†	0.01*
B. Second multivariate model			
Immediate loading/stabilization			
Yes	2.53	0.90, 7.10	0.08
No	1.00 (Ref.)		
Occlusal contacts			
Yes	1.00 (Ref.)		
No	2.53	1.00, 6.42	0.05*
Type of opposing structure			
None	0.000	‡	<0.0001
Tooth	1.00 (Ref.)		
Implant	0.19	0.02, 1.52	0.12
RPD/CD implant-supported	0.000	‡	<0.0001

*Statistically significant at ($p \leq 0.05$).

†Modeled as a continuous variable with the HR for a linear trend.

‡HR was undetermined because there were no complications for this level of the covariate.

Note: Ref. means the "reference group at each level of the covariate. The HR (hazard ratio) for the reference group is set at 1.00.

The color remained stable during the period of observation. In a recent study,[35] Diamond Crown™ was shown to have significantly better color stability than Tetric Ceram™ (Ivoclar Vivadent AG, Liechtenstein).

The supragingival plaque accumulation observed around IACs was expected, because it has been consistently shown that resin-based materials accumulate plaque at a higher rate than tooth structure and all-ceramic restorations.[36-38]

The mean sulcular depth around IACs was 3.0 mm, whereas probing depths of 2.7 to 3.3 mm have been recorded for screw- and cement-retained single-tooth implant rehabilitations.[39]

The most common postinsertion complications were the need for the adjustment of occlusal contacts and loosening of maxillary anterior restorations. Nine maxillary anterior IACs loosened on five patients; eight of them were reinserted and continued in function without further problems for the remainder of the study. One IAC loosened several times. This IAC restoring a maxillary lateral incisor was replaced with a metal–ceramic restoration splinted to an adjacent implant. This patient's occlusion consisted of seven remaining mandibular teeth, six of which were mandibular anterior teeth and one of which was a mandibular molar with no opposing occlusion. Even though the anterior region of the mouth is characterized by reduced bite forces compared to the posterior region,[40] it is reasonable to conclude that the absence of posterior support caused most of this patient's functioning to occur in the maxillary anterior region and led to the loosening of this restoration. A poor occlusal

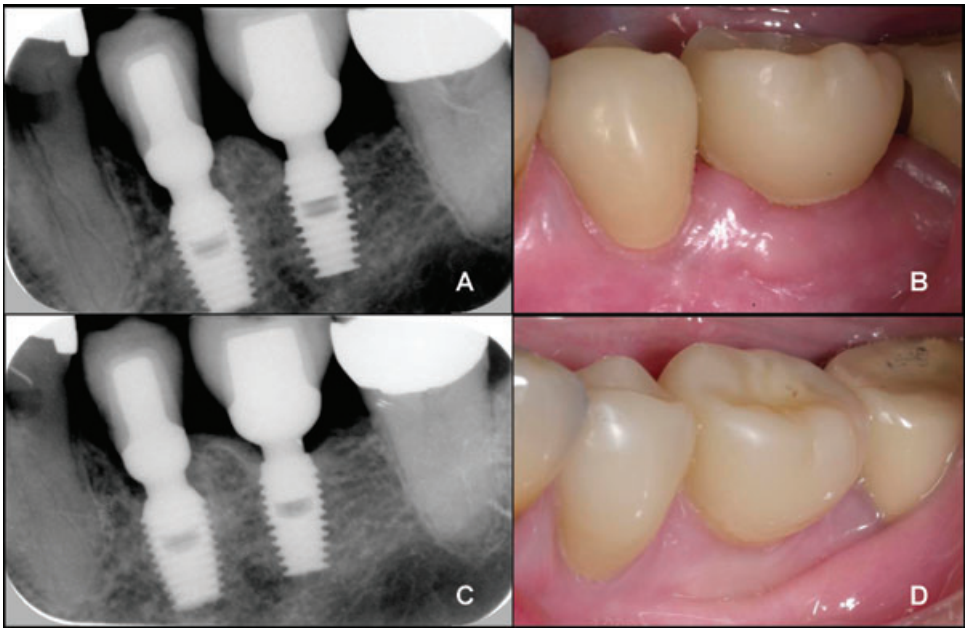

Figure 3 Periapical radiographs and clinical pictures of IACs restoring the same mandibular left bicuspid and first molar area presented in Figure 2. At crown insertion, June 2002 (A, B) and at a recall appointment, February 2004 (C, D).

scheme both increases the magnitude of loads and intensifies mechanical stresses. These factors increase the frequency of complications of implant restorations and/or bone support.[40]

To evaluate the potential risk factors associated with postinsertion complications, two multivariate Cox regression models were developed. The possible relationship between these risk factors and the most common complication, loosening of maxillary anterior IACs, was also investigated.

Based on the data shown in Table 4B, it can be concluded that IACs without contact in maximal intercuspation were

Figure 4 Clinical and radiographic view of an IAC on a maxillary right second premolar, at crown insertion (A, B), and at the recall appointment 27 months later (C, D).

2.53 times more likely to have postinsertion complications ($p = 0.05$). Biting sensitivity was the second most common complication and required the adjustment of occlusal contacts in the weeks following the insertion of four IACs. These adjustments resulted in the fact that a majority of IACs with complications lacked occlusal contacts at the time of the recall examination. Therefore, the absence of occlusal contacts did not make the restorations more likely to have complications, but rather was a consequence of the treatment provided for biting sensitivity. No association was observed between presence of occlusal contacts and loosening of maxillary anterior IACs.

IACs with deficient anatomic form and IACs positioned between a tooth and an implant were more likely to have postinsertion complications (Table 4A); however, only positioning between a tooth and an implant was found to have a statistically significant effect on loosening of maxillary anterior IACs.

To explain the loosening of maxillary anterior IACs, two hypotheses are presented. The first theory is that the restorations loosened in response to masticatory forces. In class I occlusal relationships, mandibular anterior teeth occlude with the palatal surfaces of the maxillary anterior teeth, producing forces that are oblique to their long axis. For implants in the maxillary anterior area, these lateral loads make the crown height act as a lever and a force magnifier for any offset occlusal loads. This may lead to an increase in faciolingual microrotation[41] and could have caused the loosening of the maxillary anterior IACs.

Another possible explanation for the loosening of the IACs could have been the clinician's failure to properly engage the locking taper connection. This hypothesis appears to be supported by the fact that anatomic considerations in the maxillary anterior area limit a clinician's ability to effectively apply a seating force along the long axis of the implant during the insertion of the restoration.

The placement of a maxillary anterior implant rarely corresponds exactly to the crown-root position of the original tooth. After tooth loss, the thin labial bone remodels with the alveolar crest shifting palatally; therefore, necessitating the more palatal placement of the implant.[42] Hence, the long axis of a maxillary anterior implant crown frequently has a different trajectory than the long axis of its implant.

To effectively engage the locking taper connection, the seating forces must be directed in the long axis of the implant. Tapping on the incisal edges of most maxillary anterior IACs will not direct the forces along the long axis of the implant; whereas a similar force applied on the occlusal surface of a posterior IAC is more likely to be directed vertically in the same axis as the implant and, as a result, more effectively engage its taper connection.

The stability of the connection between locking-taper implants and the crown–abutment complexes for maxillary anterior IACs should be substantiated by a long-term evaluation of the study group.

Conclusions

The screwless and cementless implant restorations presented in this study showed a survival rate of 98.7%, excellent marginal adaptation with a cementless interface, color stability, and a reduced number of prosthetic components. Plaque accumulation was observed around the crown material. The surface texture had higher roughness. The duration of the follow-up did not allow for a long-term assessment of the IACs.

The results of this study demonstrate that IACs located between a tooth and an implant were 2.65 times more likely to have postinsertion complications ($p = 0.05$). IACs with incorrect anatomic form (overcontoured) were 3.26 times more likely to have postinsertion complications ($p = 0.01$).

The most common complication observed was loosening of nine maxillary anterior IACs. Of the IACs that loosened nine (100%) were opposing natural teeth, six (66%) were adjacent to one tooth-one implant, and five (56%) implants had been immediately loaded. Maxillary anterior IACs adjacent to one tooth and one implant were 3.9 times more likely to come loose ($p = 0.05$).

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