Mechanical Evaluation of Four Narrow-Diameter Implant Systems

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Purpose: This study aimed to evaluate the survival probability of four narrow-diameter implant systems when subjected to fatigue loading. ***Materials and Methods:*** Seventy-two narrow-diameter implants to be restored with single-unit crowns were divided into four groups (n = 18): Astra Tech (3.5-mm diameter), with a standard connection (ASC); BioHorizon (3.4-mm diameter), with a standard connection (BSC); Intra-Lock (3.4-mm diameter), with a standard multilobular connection (ISC); and Intra-Lock (3.4-diameter), with a modified square connection (IMC). The corresponding abutments were screwed onto the implants, and standardized metal crowns (maxillary central incisors) were cemented and subjected to step-stress accelerated life testing in water. Use-level probability Weibull curves and reliability for 100,000 cycles at 150 and 200 N (90% two-sided confidence intervals) were calculated. Polarized light and scanning electron microscopes were used to access the failure modes. ***Results:*** The calculated survival probability for 100,000 cycles at 150 N was approximately 93% in group ASC, 98% in group BSC, 94% in group ISC, and 99% in group IMC. At 200 N, the survival rate was estimated to be approximately < 0.1% for ASC, 77% for BSC, 34% for ISC, and 93% for IMC. Abutment screw fracture was the main failure mode for all groups. ***Conclusions:*** Although the probability of survival was not significantly different among systems at a load of 150 N, a significant decrease was observed at 200 N for all groups except IMC. *Int J Prosthodont 2014;27:359–362. doi: 10.11607/ijp.3926*

Recently, the use of narrow-diameter implants has gained attention in implant dentistry. Narrow-diameter implants allow dental restorations to be inserted in areas that would otherwise require grafting procedures or in areas with limited prosthetic space (eg, the incisor region).[1] However, little is known about the mechanical performance of different implant-abutment connection designs for narrow-diameter implants.[2] Therefore, this study evaluated the survival probability and failure modes of four narrow-diameter implant systems when subjected to step-stress accelerated life testing (SSALT).

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Materials and Methods

Four narrow-diameter implant systems (n = 18) were selected and are described in Table 1. The Intra-Lock, with a standard multilobular connection (ISC), and same brand name with a modified square connection (IMC), were identical in external geometry but different in terms of their internal female abutment and screw design (Fig 1).

Abutments were connected to implants and vertically embedded in polymethyl methacrylate resin (Orthodontic Resin, Dentsply-Caulk). Groups were restored with metal crowns (maxillary central incisors) milled and produced from a single .STL file, which fabricated identical samples (cobalt-chromium metal alloy). The abutments were torqued (Tohnichi BTG150CN-S, Tohnichi-America) as per the manufacturer's instructions, and the crowns were cemented (Rely-X Unicem, 3M ESPE).

Table 1 Narrow-Diameter Implant Systems

Group	Diameter (mm)	Implant-abutment connection	Implant system	Manufacturer
ASC	3.5	TiDesign (standard prefabricated titanium connection)	Astra OsseoSpeed TX Small	Astra Tech
BSC	3.5	PYNEA (standard prefabricated titanium connection)	Tapered Tissue Level	BioHorizons
ISC	3.4	SQ (standard multilobular connection)	Intra-Lock narrow	Intra-Lock
IMC	3.4	SQ2 (modified square connection)	Intra-Lock narrow neck	Intra-Lock

Table 2 Reliability of the Specimens for 100,000 Cycles at Loads of 150 and 200 N

	ASC		BSC		ISC		IMC	
	150 N	200 N	150 N	200 N	150 N	200 N	150 N	200 N
Reliability								
Upper	0.98	0.16	1.00	0.89	0.98	0.56	1.00	0.97
Mean*	0.93^{a}	0.01^{c}	0.98^{a}	0.77^{b}	0.94^{a}	0.34^{b}	0.99^{a}	0.93^{a}
Lower	0.75	2.03 (10^{-6})	0.93	0.55	0.80	0.13	0.98	0.81
β								
Upper	3.55		2.37		4.57		3.12	
Mean	2.10		1.34		3.19		2.10	
Lower	1.24		0.75		2.22		1.41	

*Same superscript letters among groups within the same load comparisons (150 N or 200 N) indicate statistically homogeneous groups.

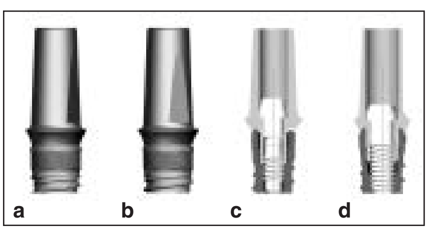

Fig 1 **(a, c)** ISC and **(b, d)** IMC designs with identical external geometries. The only differences reside in the abutment and retaining screw designs.

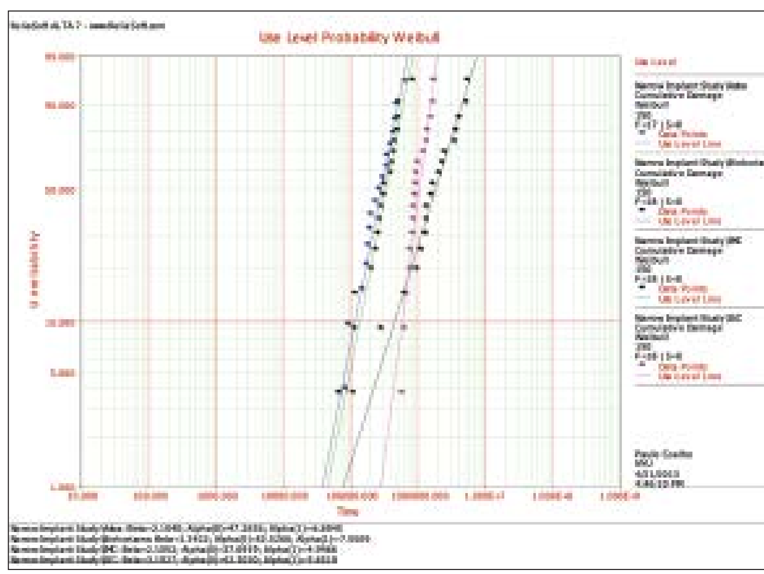

Fig 2 *(right)* Use-level probability Weibull curve showing the probability of failure as a function of number of cycles (time) for 100,000 cycles at 150 N.

Mechanical testing was conducted with the specimens positioned at a 30-degree axial inclination, under water, and at 9 Hz (800L, TestResources)[3] until failure (ie, fracture or bending of the fixation screw, abutment, and/or implant) or survival of step-stress profiles.

Use-level probability Weibull curves with use loads of 150 and 200 N (90% two-sided confidence intervals [CIs]) were calculated and plotted (Alta-Pro 7, ReliaSoft) using a power-law relationship for damage accumulation. The failed samples were subjected to fractographic analysis in the scanning electron microscope (SEM; S-3500N, Hitachi).

Results

The mean β values (CIs) derived from use-level probability Weibull calculations were 2.10 (1.24 to 3.55), 1.34 (0.75 to 2.37), 3.19 (2.22 to 4.57), and 2.10 (1.41 to 3.12) for the Astra Tech standard connection (ASC), BioHorizon standard connection (BSC), ISC, and IMC groups, respectively (Table 2; Fig 2).

The survival probabilities after 100,000 cycles at a load of 150 N were 93% in group ASC, 98% in group BSC, 94% in group ISC, and 99% in group IMC. At a load of 200 N, the survival probabilities were < 0.1%

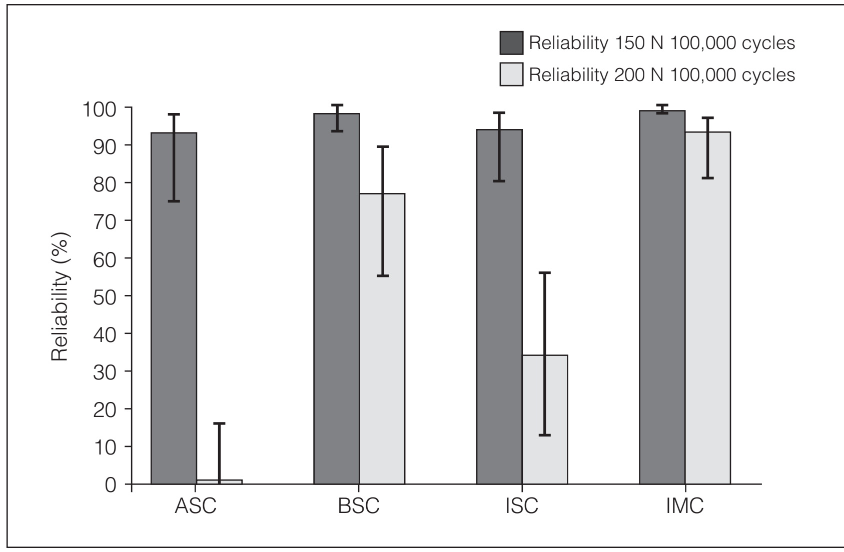

Fig 3 Reliability of the specimens for 100,000 cycles at loads of 150 N and 200 N.

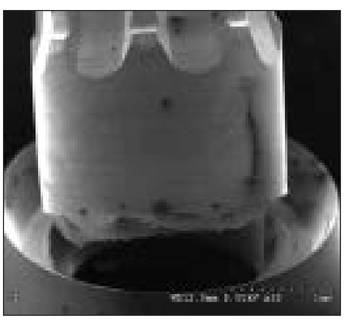

Fig 4 SEM micrograph of an abutment fracture (magnification ×35).

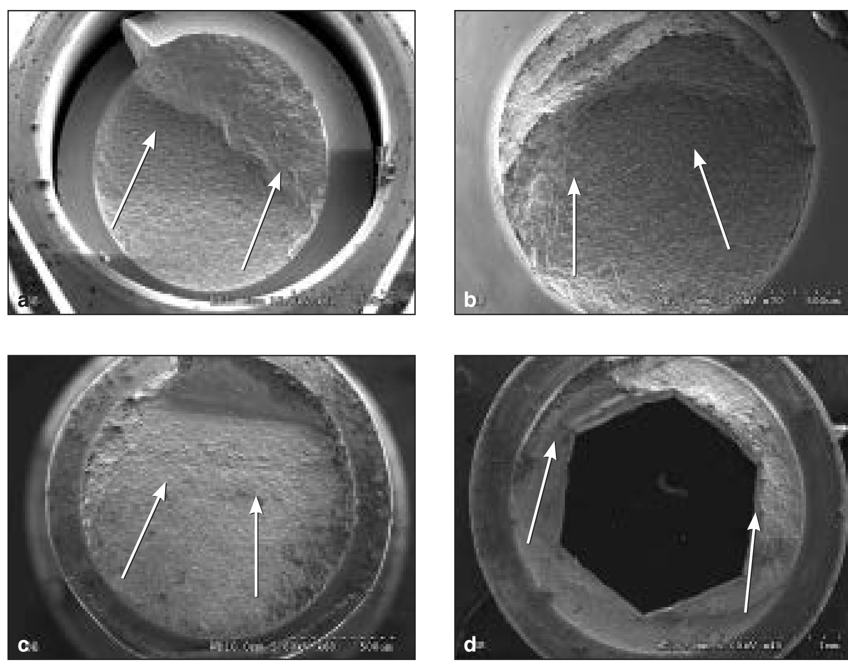

Fig 5 *(right)* SEM micrographs of representative fractures after SSALT. **(a)** Long-axis view of fractured abutment screw in group ASC; the arrows point toward the compression curl, while the opposite tensile side indicates its origin. The angulations of the arrows indicate the direction of crack propagation. Failure in groups **(b)** BSC, **(c)** ISC, and **(d)** IMC involved the same failure pattern.

for the Astra Tech standard connection (ASC), 77% for the BioHorizon standard connection (BSC) group, 34% for the ISC group, and 93% for the IMC group (see Table 2). The values at 150 N were not significantly different among the systems tested. At a 200-N load, a significant decrease in reliability was observed for all groups, although group IMC maintained the highest reliability values (Fig 3).

All specimens failed during SSALT through a combination of abutment screw bending or fracture and abutment fracture (Figs 4 and 5; Table 3).

Table 3 Failure Modes After SSALT

	ASC (n = 17*)	BSC (n = 18)	ISC (n = 18)	IMC (n = 18)
Implant	18 intact	18 intact	18 intact	18 intact
Abutment	3 bending 14 fracture	5 bending 13 fracture	1 intact 17 fracture	3 bending 15 fracture
Screw	13 fracture 4 intact	14 fracture 4 intact	18 fracture	16 fracture 2 intact

*One sample failed.

Discussion

The survival probability decreased at 200 N (100,00 cycles) for all groups—although very slightly for group IMC. This result was unexpected given that the implants were of similar dimensions. It is possible that the IMC configuration shields the abutment and screw from higher load levels. Further, the IMC design has a four-sided internal configuration that provides improved fit and thus decreases micromovements between parts.[4] This increased fit is remarkably important because the moment of inertia in bending is proportional to the inverse of the cube of the diameter of the part; thus, even small changes in fit will result in exponential variations in the system's bending resistance. Future studies evaluating this issue are warranted.

The failure mode in the IMC group was screw fracture at the third thread region. This may be due to the increased cross-sectional area of the connection in this group. In other groups, the screw head region was critical in terms of endurance of the prosthetic components, likely due to the shift in geometry along its length.[5] In this study, cycles were accelerated for reliability analysis, which precluded an extrapolation of years of clinical usage.

Conclusions

The survival probability was not significantly different among the implant systems at a load of 150 N. At a load of 200 N, the survival probabilities decreased significantly, except for in the group with internal modified square connections.

Acknowledgments

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Literature Abstract

Long-term stability of early implant placement with contour augmentation

The authors reported outcomes of early implant placement with simultaneous contour augmentation for a maxillary anterior single-tooth. Twenty patients were selected and followed for 6 years. Details of case selection and surgical and restorative procedures have been reported in previous publications (at 1 and 3 years). Special emphasis was placed on assessing the stability of the facial mucosa. Results showed that all implants were firmly integrated during the 6-year study period. Good stability of peri-implant soft tissues with a mean facial keratinized mucosa of more than 4 mm and pleasing esthetic outcomes were achieved. Cone beam computed tomography demonstrated that all 20 implants had a detectable facial bone wall. The authors suggested using histomorphometric analysis to show what percentage of this facial wall is bone versus remaining graft material. It was concluded that early implant placement with simultaneous contour augmentation offers high predictability for successful esthetic outcomes and good long-term stability of the established facial bone wall.

Buser D, Chappuis V, Kuchler U, Bornstein MM, Wittneben JG, Buser R, Cavusoglu Y, Belser UC. *J Dent Res* 2013;92(suppl 12):176S–182S. **References:** 32. **Reprints and Email:** daniel.buser@zmk.unibe.ch—*Huong Nguyen, Ann Arbor, Michigan, USA*