Internal- vs External-Connection Single Implants: A Retrospective Study in an Italian Population Treated by Certified Prosthodontists

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Purpose: *The design of an implant connection that allows prosthetic suprastructures to be attached to implants has long been debated in the dental literature. The goal of this retrospective study was to evaluate the 5-year clinical results for a large number of single implants restored by certified prosthodontists in an attempt to establish whether different clinical outcomes could be detected for external- or internal-connection implants.* ***Materials and Methods:*** *All single implants with internal or external connections inserted in 27 private dental practices from January 1, 2003 to December 31, 2007 were evaluated. An initial statistical analysis was performed to describe the sample population at baseline and then to compare the two types of implant-abutment connection configurations and their clinical outcomes. All data were statistically analyzed with STATA12 (StataCorp).* ***Results:*** *Twenty-eight of the 85 active members of the Italian Academy of Prosthetic Dentistry (AIOP) participated in this study. The sample included 1,159 patients and 2,010 implants. Of the implants, 75 were dropped because there was no information about follow-up. Of the remaining implants, 1,431 (74.0%) were followed for at least 5 years, and 332 implants (17.2%) were followed for more than 8 years. Nearly 99% (98.9%) of the implants survived. The difference between the survival frequencies of the two types of implant-abutment connection configurations was not significant for each negative event (log-rank test, $P > .05$). There was no difference between the two types of implants regarding restoration fracture, implant screw loosening, and peri-implant disease.* ***Conclusion:*** *Within the limitations of this study, it can be suggested that there is no difference in clinical outcomes of single restorations joined to internal- or external-connection implants.* Int J Oral Maxillofac Implants 2016;31:1385–1396. doi: 10.11607/jomi.4618

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The Brånemark system was introduced to the scientific community in the 1960s and 1970s. Since then, many implant systems have been presented to the dental profession.[1–5] The design of the connection that allows the prosthetic suprastructure to be attached to the implants is one of the features that has been the object of discussion among the systems. From the beginning, the Brånemark system was typified by an external hexagon, which was developed to facilitate implant insertion rather than to provide clinicians with an antirotational device.[2] This external-hexagon configuration has served well over the years and has been

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incorporated into several competing systems. However, this configuration has some negative aspects due to its limited height and, as a consequence, limited effectiveness when subjected to off-axis loads.[6] Therefore, it has been speculated that, under high occlusal loads, the external hexagon might allow for micromovements of the abutment, thus causing instability of the joint, which may result in abutment screw loosening or even fatigue fracture.[7–9]

Internal connections have been introduced to reduce or eliminate these mechanical complications and reduce stress transferred to the crestal bone.[10–13] A primary question is whether this may be true for all internal-connection systems,[14–16] since, unlike the external-hexagon connection, the internal-connection configurations adopted by different companies are not alike. When the implant-abutment couplings of internal-connecting systems have been analyzed, many differences have been described,[16–20] such as the intimacy of approximation between the abutment surface and the internal walls of the implant fixture (no friction vs Morse taper), the depth of penetration of the abutment in the fixture, the presence of antirotational interlocking, the numbers and shapes of antirotational or guiding grooves (hexagon, trilobe, spline, etc), the abutment diameter at the platform level (matched vs narrower, to generate a platform shift or switch), the abutment screw dimension and material, the screw preload, and the abutment materials (titanium, precious metal alloys, full zirconia, zirconia with metal inserts). These differences could have a profound impact on the clinical procedures and protocols, chair time dedicated to the patient, number of appointments, laboratory and component costs, maintenance intervals, and incidence of complications.

When the clinician is fabricating an implant-supported fixed dental prosthesis (FDP), a major concern to ensure its longevity is to minimize mechanical complications. Many publications in the literature deal with the incidence of screw loosening or fracture, as well as with the incidence of abutment and implant fracture. Four literature reviews[21–24] have provided in-depth analyses of the topic. These papers highlight and analyze the major factors that may cause mechanical complications such as screw material,[19] screw preload,[25–28] abutment material,[29,30] abutment rotational misfit,[31–33] implant-abutment connection configuration,[34–36] implant angulation,[37] thickness of implant neck walls,[38,39] and single vs splinted crowns.[40–43] In particular, after the change in the abutment screw material in the 1990s, and the recommendation of system-specific torque values for these screws, the type of implant-abutment connection configuration has been identified as the most relevant variable that can ensure implant-abutment joint stability. It has been postulated that internal implant-abutment connections demonstrate higher resistance to bending and improved force distribution over external configurations[44,45] because of their ability to dissipate lateral loads deeply within the implant and to resist joint opening.[16,20,24,46] The internal implant-abutment connections also displayed improved shielding of the abutment screw from stress.[11]

The use of high-strength ceramics, previously alumina and presently zirconia, has provided an alternative to metal abutments.[47] When polycrystalline ceramic implant abutments are used in the clinical situation, there are concerns about the risk of fracture due to the material's brittle nature. This is especially true in internal-connection systems, where the interlocking portion may be particularly thin. As a matter of fact, several manufacturing companies do not provide zirconia abutments for their narrow-platform implants. In vitro studies have provided some insight into the behavior of ceramic abutments in different types of implant systems,[24,46,48–51] but it is difficult to draw clinically relevant recommendations from them. One of the difficulties in ascribing clinical value to the results of in vitro studies has to do with the lack of evidence for diverse methods of loading implant abutments. They differ with regard to type of loading (static loading or dynamic fatigue loading, lateral-oblique loading,[17–19] or rotational fatigue loading[17]); loading angle (from 0 to 90 degrees); loading point (incisal edge or a nonspecified point on the palatal surface); and applied load (light forces or forces that exceed the maximum occlusal force recorded in humans). It is debatable which is the most clinically relevant method. For that reason, analysis of the clinical performance can best demonstrate the reliability of the prosthetic devices. Two very thorough systematic reviews of the performance of ceramic and metal implant abutments[52] and of zirconia abutments only[53] have been published recently. In comparing the outcome of the study on ceramic abutments with that of the study on metal abutments, the authors of the first systematic review concluded that no difference in the clinical performance of the two types of abutments could be perceived.[52,54–58] The authors of the second systematic review[53] reached the same conclusions, highlighting the fact that, in this short to medium period of evaluation, no relevant mechanical complications occurred.[56–58] In a recent literature review,[59] it has been pointed out that the incidence of fracture of metal-based and zirconia-based abutments and the incidence of abutment screw fracture did not seem to be influenced by the type of connection. Furthermore, an analysis of the literature showed that loosening of abutment screws was the most frequently occurring technical complication; the type of connection seemed to have an influence on the incidence of screw loosening: more loose screws were reported for externally connected implant systems for both types of materials.

The aim of this retrospective study was to evaluate the 5-year clinical outcomes of a large number of single implants restored by certified prosthodontists in an attempt to establish whether different clinical behaviors may be detected for external- or internal-connection implants. The negative events (biologic and mechanical, irreversible and reversible) were evaluated for both types of connection.

MATERIALS AND METHODS

Patient Selection

In January 2014, 85 active members of the Italian Academy of Prosthetic Dentistry (AIOP) were asked to complete a Microsoft Excel spreadsheet with information regarding implants inserted from January 1, 2003 to December 31, 2007. The deadline to reply was September 30, 2014.

The selected patients were treated in private dental practices. Inclusion criteria were that each patient had an intact arch at least up to the second premolars and received one or more single-implant metal-ceramic crowns, with each implant exclusively supporting a single restoration.

The exclusion criteria were[60–62]: patients with poor oral hygiene; presence of irreversible active periodontal problems; severe diabetes (especially type 1) and other diseases, which could cause periodontal problems; and patients taking medications that could influence periodontal status. Moreover, implants whose connection type was unknown had to be excluded. For each single implant, the AIOP prosthodontist had to report:

1. A sequential numeric code for each surgeon and technician working with the AIOP member
2. Sex of patients
3. Date of birth, implant insertion, definitive prosthetic restoration delivery, and the last follow-up
4. Number of cigarettes smoked per day
5. Number of professional tooth-cleaning procedures per year
6. Dental implant site
7. Implant-abutment connection configuration (external or internal)
8. Peri-implant supplementary or additional surgery (before, simultaneously, none)
9. Functional load (immediate or delayed)
10. Type of occlusal guide (canine incisive, canine, group, other)
11. Provisional restoration
12. Crown retention (cemented or screwed)
13. Prosthetic margin (supragingival, subgingival, or extragingival)
14. Abutment material (titanium, zirconia, metal-zirconia, alumina, and gold)
15. Crown material (metal-ceramic crown, zirconia-ceramic crown)
16. Type of opposite arch (tooth, crown on tooth, crown on implant, pontic, denture, generic crown, none)
17. Opposite arch material (metal, resin, ceramic, and zirconia)
18. Tooth wear
19. Bruxism habit
20. Use of occlusal nightguard
21. Implant commercial brand
22. Implant commercial code
23. Probing depth
24. Insertion torque
25. Patients lost to follow-up
26. Number of unscrewing events and date of the first event
27. Screw fracture event and date
28. Abutment fracture event and date
29. Implant fracture event and date
30. Restoration-material fracture event and date
31. Peri-implantitis event (abscess, bone loss, and mobility) and date of first event

Statistical Analysis

Each prosthodontist was identified with a code masked for the statistician, who created, cleaned, and elaborated the final datasets. Uncorrected or unintelligible answers were classified as missing values.

The statistical analysis was performed at first to describe the sample population at baseline and then to compare the two types of implant-abutment connection configurations. To evaluate the difference in frequency between categories of sex or implant-abutment connection configuration, the Pearson χ^2 test and the Fisher exact test were run. For the continuous variables (waiting time before screw load, mucosal canal, and insertion torque), the two-sample Wilcoxon rank-sum test was applied. A nonparametric test was used for nonnormally distributed variables (Shapiro-Wilk test, $P < .001$).

The analysis of complications was performed by means of the log-rank test and the Cox proportional regression model for comparison of the survival curves of the two types of implant-abutment connection configurations and to control for confounders. In the Cox model building, a step-forward selection of exposures was performed. One of the exposures (peri-implant surgery) did not respect the assumption of proportional hazard; therefore, the model was adjusted by stratification. For each statistical test, the α-level was fixed at .05.

Table 1 Descriptive Statistics of Patient Samples

	No.	Total missing values
Sample size (N)	1,159	14
Mean ± SD age at first implant (y)	49.6 ± 13.0	23
Males		
No. of patients (%)	481 (41.9%)	11
Mean ± SD age at first implant (y)	49.3 ± 12.6	
No. of implants in males	821 (42.8%)	
Females		
No. of patients (%)	667 (58.1%)	
Mean ± SD age at first implant (y)	47.6 ± 9.4	
No. of implants in females	1,097 (57.2%)	
No. of patients lost to follow-up (%)	225 (19.7%)	
Percent of males	19.9%	
Percent of females	19.5%	
No. of patients reporting bruxism habit (%)	265 (23.6%)	38
No. of patients with tooth wear (%)	550 (52.3%)	108
No. of cigarettes smoked per day (mean ± SD)	2.4 ± 5.5	11
0 cigarette/day No. of patients (%)	878 (76.5%)	
Below 6 cigarettes/day No. of patients (%)	99 (8.6%)	
6–10 cigarettes/day No. of patients (%)	78 (6.8%)	
11–20 cigarettes/day No. of patients (%)	87 (7.8%)	
More than 20 cigarettes/day No. of patients (%)	6 (0.5%)	
No. of professional tooth-cleanings per year (mean ± SD)	2.2 ± 1.0	13
Any professional tooth-cleaning/year No.of patients (%)	56 (4.9%)	
One professional tooth-cleaning/year No. of patients (%)	148 (12.9%)	
Two professional tooth-cleanings/year No. of patients (%)	552 (47.6%)	
More than two professional tooth-cleanings/year No. of patients (%)	390 (34.0%)	
Occlusal guide		
No. of patients	1,057	102
Canine incisor No. of patients (%)	485 (45.9%)	
Canine No. of patients (%)	277 (26.2%)	
Group No. of patients (%)	254 (24.0%)	
Other No. of patients (%)	41 (3.9%)	
Occlusal nightguard		
No. of patients (%)	173 (16.3%)	98

The authors estimated the sample size a priori by hypothesizing some scenarios in the survival study (sample size calculation for a log-rank test), because hazard ratio (HR) and the number of patients lost to follow-up were not easily predictable. The first scenario was comprised of the following features: α-level = .05, HR = 0.5, power = 0.80, proportion of subjects in control group = 0.5, and rate of censoring = 0.20. The estimated sample size was 45 implants for each type of implant-abutment connection configuration. When the lost-to-follow-up group was changed to 30%, the sample needed to be increased to 51 implants per group, while by increasing the HR to 0.8, it amounted to 398 per group. However, where there might be an imbalance between the two groups—for example, with a ratio of 0.7 for the first group and 0.3 for the second—the sample was divided into 723 and 310 implants, respectively (1,033 in total). It increased to 826 and 354, respectively (1,180 in total), with 30% lost to follow-up. Therefore, a target of 1,000 implants was fixed a priori by the end of September 2014.

All data were statistically analyzed with STATA12 (StataCorp).

RESULTS

Of 85 active AIOP members, 28 submitted the completed spreadsheet by the deadline. The sample was comprised of 1,159 patients and 2,010 implants.

Patient Sample and Implant Sample

The sample was comprised of 1,159 patients with a mean ± SD age at first implant of 49.6 ± 13.0 years: 481 were males (41.9%; mean age, 49.3 ± 12.6 years) and 667 females (58.1%; mean age, 47.6 ± 9.4 years; Table 1).

When age was divided by categories of 10 years, the distribution of people was equal between males and females (chi^2, *P* = .206). Seventy-one percent (70.9%) of all patients (Fig 1) were between 30 and 59 years of age.

The frequency distribution of occlusal guides among patients showed a predominance of the canine-incisive guide (45.9%) over canine (26.2%) and group (24.0%) guides.

Patients were predominantly nonsmokers (76.5%) or low-smokers (below 6 cigarettes per day, 85.1%).

Two hundred sixty-five patients reported a bruxism habit (23.6%), and 550 (52.3%) presented tooth wear (49.3% of males vs 45.6% of females; Fisher test, *P* = .014). One hundred seventy-three patients (16.3%) were accustomed to using an occlusal nightguard. When the group with bruxism habits was considered exclusively, the percentage of occlusal nightguard users was 62.8% among females vs 50.4% among males (chi^2, $P = .041$).

The frequency of professional tooth-cleaning per year was at least once every 6 months in 82.2% of patients.

Within the 2,010 implants of the sample, 821 implants (42.8%) were inserted in males and 1,097 implants (57.2%) in females.

There were 14 patients without any kind of information. Furthermore, the number lost to follow-up was 225 (19.7%). The percentages of males and females lost to follow-up were very close: 19.9% among males and 19.5% among females.

In the sample of 2,010 implants, 968 (48.2%) had an internal connection, and 1,042 (51.8%) an external connection (Table 2).

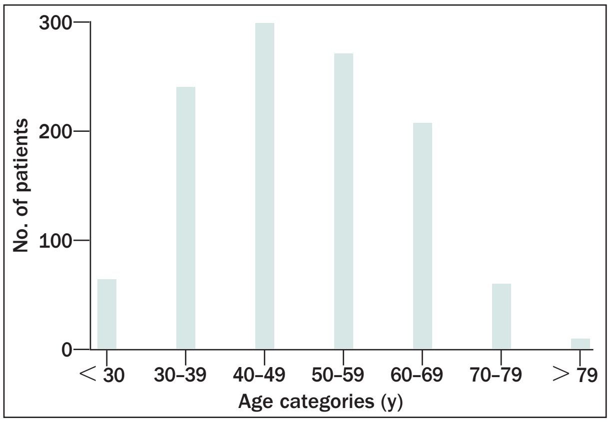

Fig 1 Distribution of patients by age across categories over 10 years.

Implant Frequency Distribution Across Dental Arch Areas

When the anterior (incisors and canines) and posterior (premolars and molars) areas of the dental arches were analyzed, 42.8% of implants were found to be in the posterior maxillary and 44.1% in the posterior mandibular areas, with only 9.8% in the anterior maxillary and 3.4% in the anterior mandibular areas.

The distribution per dental arch area of implant-abutment connection configurations presented similar percentages in the two groups.

Provisional Restoration and Screw Load

One thousand three hundred seventy-three implants (68.3%) received a provisional restoration without a significant difference between the two types of connections (chi^2 test, $P = .662$).

The load was delayed in 1,904 implants (68.3%). The prevalence was similar between internal- and external-connection groups (chi^2 test, $P = .165$). In fact, the majority of implants were loaded after a period of time, with the median waiting time 7.8 months (interquartile range: Iqr, 8.3). In the internal-connection group, the implants were loaded, on average, earlier than in the external-connection group (two-sample Wilcoxon rank-sum test, $P = .0001$): 7.4 months (Iqr, 6.8) vs 8.2 months (Iqr, 10.3), respectively.

Where stratification for the dental arch is concerned, there was no difference in the mandibular arch between the two types of connections (internal connection: median, 6.7 months; Iqr, 6.5; external connection: median, 6.8 months; Iqr, 9.5; two-sample Wilcoxon rank-sum test, $P = .2146$). On the contrary, the difference was significant in the maxillary arch (two-sample Wilcoxon rank-sum test, $P < .001$). In the maxillary posterior area, the screws were loaded earlier in the internal-connection (median, 8.2 months; Iqr, 6.6) than in the external-connection (median, 11.0 months; Iqr, 10.7) implants (two-sample Wilcoxon rank-sum test, $P < .001$). In the maxillary anterior area, the median values were dissimilar (internal connection: median, 8.8 months; Iqr, 8.8; external connection: median, 10.6 months; Iqr, 8.6); however, the difference did not show a significant result (two-sample Wilcoxon rank-sum test, $P = .0899$).

Probing Depth and Insertion Torque

The majority of implants had a probing depth of 2 to 3 mm (76% of implants) with no difference between the two types of connections (two-sample Wilcoxon rank-sum test, $P = .1639$).

In the sample, 55.9% of implants were inserted with a torque between 25 and 35 Ncm, 19.4% with a torque below 25 Ncm, and 24.7% above 35 Ncm.

The difference in median values of torque between the two connection groups was significant: 30 Ncm (Iqr, 0) in the external-connection group vs 32.0 Ncm (Iqr, 2.0) in the internal-connection group (two-sample Wilcoxon rank-sum test, $P < .001$).

Supplementary or Additional Surgery

The majority of implants (72.8%) did not require a supplementary or additional surgical procedure at the site. In 20.6% of implants, the regenerative surgery was accomplished simultaneously at the time of insertion. The occurrence of this surgical treatment was similar between the two connection groups (chi^2 test, $P = .448$).

Abutment Material

In the full sample, the abutments were made primarily of titanium (65.77%), followed by gold (19.45%) and zirconia (13.71%). Metal-zirconia (1.02%) and alumina (0.05%) were rarely used. In stratification for implant-abutment connection configuration, in the group with an internal connection, 79.5% of abutments were made of titanium, 13.2% of gold, and 5.5% of zirconia.

Table 2 Features of Implant Sample

	Implant-abutment connection configuration		Missing values	Total[a]
	Internal	External		
Sample, n (%)	968 (48.2%)	1,042 (51.8%)	0	2,010
Arch				
No. of implants	950	1,009	51	1,959
Posterior maxilla				
No. of implants (%)	419 (50.0%)	419 (50.0%)		838 (42.8%)
Anterior maxilla				
No. of implants (%)	96 (50.0%)	96 (50.0%)		192 (9.8%)
Posterior mandible				
No. of implants (%)	417 (48.3%)	446 (51.7%)		863 (44.1%)
Anterior mandible				
No. of implants (%)	18 (27.3%)	48 (72.7%)		66 (3.4%)
Waiting time for implants with delayed load				
Median (Iqr[b]), mo	7.4 (6.8)	8.2 (10.3)	80	7.8 (8.3)
Insertion torque				
Median (Iqr[b]), mo	32.0 (2.0)	30.0 (0.0)	52	32 (2.0)
Probing depth				
Median (Iqr[b]), mm	2.0 (1.0)	2.0 (1.0)	297	2.0 (1.0)
Peri-implant supplemental or additional surgery				
No. of implants	968	1,041	1	2,009
No surgery				
No. of implants (%)	692 (47.3%)	770 (52.7%)		1,462 (72.8%)
Before implant insertion				
No. of implants (%)	66 (49.6%)	67 (50.4%)		133 (6.6%)
Simultaneous implant insertion				
No. of implants (%)	210 (50.7%)	204 (49.3%)		414 (20.6%)
Abutment material				
No. of implants	961	1,008	41	1,969
Titanium				
No. of implants (%)	764 (59.0%)	531 (41.0%)		1,295 (65.7%)
Zirconia				
No. of implants (%)	53 (19.6%)	217 (80.4%)		270 (13.7%)
Metal-zirconia				
No. of implants (%)	17 (85.0%)	3 (15.0%)		20 (1.0%)
Alumina				
No. of implants (%)	0	1 (100%)		1 (0.1%)
Gold				
No. of implants (%)	127 (33.2%)	256 (66.8%)		383 (19.5%)
Type of prosthetic restoration				
No. of implants	967	1,040	3	2,007
Cemented crown retention				
No. of implants (%)	764 (52.2%)	700 (47.8%)		1,464 (72.9%)
Screwed crown retention				
No. of implants (%)	203 (37.4%)	340 (62.6%)		543 (27.1%)
Prosthetic margin				
No. of implants	859	743	408	1,602
Supragingival				
No. of implants (%)	12 (44.4%)	15 (55.6%)		27 (1.7%)
Subgingival				
No. of implants (%)	342 (60.9%)	220 (39.1%)		562 (35.1%)
Extragingival				
No. of implants (%)	505 (49.9%)	508 (50.1%)		1,013 (63.2%)
Type of prosthetic crown restoration				
No. of implants	961	1,008	41	1,969
Metal-ceramic crowns				
No. of implants (%)	723 (50.6%)	705 (49.4%)		1,428 (72.5%)
Zirconia-ceramic crowns				
No. of implants (%)	238 (44%)	303 (56%)		541 (27.5%)

[a]Number of implants analyzed and percentage within the full sample.
[b]Iqr = interquartile range.

In contrast, in the group with an external configuration, the prevalence of titanium decreased to 52.7%, while the use of gold and zirconia increased to 25.4% and 21.5%, respectively (chi^2 test, $P < .001$).

Type of Prosthetic Restoration

There was a higher prevalence of cemented (72.9%) than screwed (27.1%) implants used for crown retention. However, the prevalence of cemented crown retention in the external-connection group was 47.8% vs 52.2% in the internal-connection group; for screwed crown retention, it was 62.6% and 37.4%, respectively (chi^2 test, $P < .001$). There was an 83.8% prevalence of metal-ceramic single restorations with ceramic in the occlusal surface; in the ceramic-zirconia crowns group (with ceramic in the occlusal surface), it was 16.2%.

Prosthetic Margin

The prosthetic margin was more frequently extragingival (63.2%), followed by subgingival (35.1%) and supragingival (1.7%). Considering only the subgingival and extragingival prosthetic margins, in both types of connections, the extragingival prosthetic margin predominated. Among the 1,013 implants with an extragingival prosthetic margin, the distribution was similar between internal and external implant-abutment connection configurations: 49.9% in the first group and 50.1% in the second group. Within the 562 implants with a subgingival prosthetic margin, 60.9% had an internal connection and 39.1% an external connection configuration (chi^2 test, $P < .001$).

Type of Opposite Arch and Opposite Arch Material

The majority of opposite arches were in sequence: teeth (56.2%), crown on tooth (22.5%), and crown on implant (15.1%). Pontics, dentures, generic crowns, and absence of opposite arch amounted all together to 6.3% of implants.

In 54.6% of implants, the opposite arch was the enamel of a natural tooth, followed by ceramic (36.8%) and resin (6.2%) of an artificial crown.

Implant Brand

The majority of implants were produced by Nobel Biocare (35.7%; Nobel Biocare), Biomet 3i (21.1%; 3i/Implant Innovations), and Resista (16.5%, WIS Implant System, Omegna). The frequency distribution of all brands stratified for implant-abutment connection configuration is reported in Table 3.

Table 3 Frequency Distribution of Implant Brands Stratified for Implant-Abutment Connection Configuration

Brand, No. of implants (%)	Implant-abutment connection configuration: Internal	External	Total
Astra Tech	33 (3.4%)	0	33 (1.6%)
Biomet 3i	161 (16.6%)	264 (25.3%)	425 (21.1%)
Camlog	80 (8.3%)	0	80 (4.0%)
DentalTech	4 (0.4%)	0	4 (0.2%)
Dentsply Friadent	9 (0.9%)	0	9 (0.5%)
Exacta	2 (0.2%)	0	2 (0.1%)
GEASS	25 (2.6%)	0	25 (1.2%)
Keystone Dental	8 (0.8%)	1 (0.1%)	9 (0.5%)
MegaGen	6 (0.6%)	0	6 (0.3%)
Micerium	0	6 (0.6%)	6 (0.3%)
MIS Implants	2 (0.2%)	0	2 (0.1%)
Neoss	14 (1.5%)	0	14 (0.7%)
Nobel Biocare	278 (28.7%)	439 (42.13%)	717 (35.7%)
PH	11 (1.1%)	0	11 (0.6%)
Resista	0	331 (31.8%)	331 (16.5%)
Shackleton	4 (0.4%)	1 (0.1%)	5 (0.3%)
Straumann	40 (4.1%)	0	40 (2.0%)
Sweden & Martina	199 (20.6%)	0	199 (9.9%)
Thommen Medical	18 (1.9%)	0	18 (0.9%)
Zimmer Dental	74 (7.6%)	0	74 (3.7%)

Negative Events

Of 2,010 implants, 75 were dropped because there was no information about follow-up, 1,431 implants (74.0%) were followed for at least 5 years, and 332 implants (17.2%) were followed for more than 8 years; 98.9% of implants survived.

Considering only implants with mechanical negative events and at least 5 years of follow-up, the frequency of these negative events due to fracture of implant, fracture of screw, fracture of abutment, or fracture of connection amounted to 16 cases, corresponding to 1.1% of the implant sample. Within the full sample, the distribution of events for each component and the log-rank test *P* value are reported in Table 4. There were 11 mechanical failures in internal vs five in external implant-abutment connection configurations. Only implant fracture could be considered an irreversible negative event. The difference between the frequencies in survival of the two types of implant-abutment connection configurations was not significant for each negative event (log-rank test, $P > .05$).

Restoration Fracture

Ceramic fractures of surfaces of metal-ceramic and zirconia-ceramic restorations amounted to 46, 2.6% of the full sample: 40 were ceramic surfaces of metal-ceramic crowns, and 6 were ceramic surfaces of zirconia-ceramic crowns. The ceramic fractures were divided as

Table 4 Frequency of Negative Events Stratified by Implant-Abutment Connection Configuration

Negative event, Frequency (%)	Implant-abutment connection configuration: Internal	Implant-abutment connection configuration: External	Missing values	Total	Log-rank test (*P*)
Implant fracture	1 (0.1%[a])	1 (0.1%[a])	192	2 (0.1%[b])	.6664
Screw fracture	3 (0.4%[a])	1 (0.1%[a])	191	4 (0.2%[b])	.1890
Abutment fracture	2 (0.2%[a])	2 (0.2%[a])	191	4 (0.2%[b])	.8359
Connection fracture	5 (0.6%[a])	1 (0.1%[a])	190	6 (0.3%[b])	.0584
Restoration fracture	20 (2.4%[a])	26 (2.9%[a])	191	46 (2.6%[b])	.9861
Implant unscrew[c]	13 (1.6%[a])	12 (1.3%[a])	197	25 (1.4%[b])	.4398
Periodontal disease	51 (6.1[a])	43 (4.7[a])	185	84 (5.4%[b])	.0381

[a]Percentage of negative events inside the group defined by the type of connection.
[b]Percentage of negative events inside the full sample.
[c]At least one unscrew event.

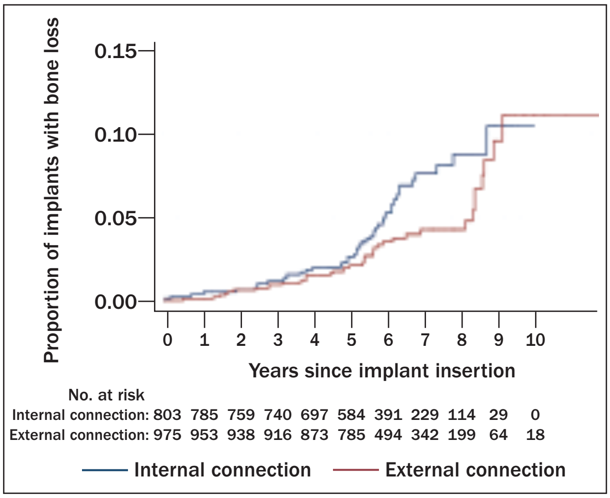

Fig 2 Kaplan-Meier failure curve for reduction in peri-implant bone level (bone loss).

follows: 20 for internal implant-abutment connection configuration (2.4%) and 26 for external connection (2.9%). The log-rank test was not significant ($P = .9861$).

Implant-Abutment Unscrewing Event

Of 1,935 implants, 1,713 (98.6%) never presented any unscrewing event of the implant-abutment interface; 21 implants (1.2%) unscrewed once, and four implants unscrewed two or more times (0.2%). In a comparison of internal vs external abutment-connection configurations, the difference was not significant for the number of "at least one unscrew event": 13 events (1.6%) in internal-connection and 12 events (1.3%) in external-connection implants (log-rank test, $P = .4398$).

Peri-implant Disease

The majority of patients (94.6%) did not develop any kind of peri-implant disease. Two patients (0.1%), one for each connection group, developed an abscess; 85 patients (4.7%) showed a bone loss in excess of 0.2 mm/year (46, 5.5%, in the internal- and 39, 4.3%, in the external-connection groups); and seven patients (0.4%) showed implant mobility, four (0.5%) in the internal-connection group and three in the external-connection group (0.3%).

Considering exclusively the bone loss in excess of 0.2 mm/year, which was the most common peri-implant manifestation, despite the small number of events, there was a nonsignificant difference in the trend of bone loss development between the two connection types: the internal-connection group showed a slightly higher tendency to have more bone loss than the external-connection group, as visualized in the Kaplan-Meier failure curve (Fig 2; log-rank test, $P = .0758$). In an analysis of the life-table, the 5-year cumulative failure rates for the internal- and external-connection groups were found to be 5.5% (95% CI, 3.9 to 7.7; survival rate, 97.2%, 95% CI, 95.6 to 98.2) and 4.0% (95% CI, 0.7 to 5.6; survival rate, 96.1%, 95% CI, 94.3 to 97.3), respectively. Cumulative failure rates increased to 11.1% (95% CI, 7.7 to 16.0; survival rate, 88.9%, 95% CI, 84.0 to 92.3) in the internal-connection group and to 11.4% (95% CI, 7.3 to 17.5; survival rate, 88.6%, 95% CI, 82.5 to 92.7) in the external-connection group at the eighth year of observation.

To analyze the risk factors for bone loss, the authors ran the Cox proportional hazard regression. After a step-forward selection of exposures, the variables implant-abutment connection configuration, smoking, insertion torque, number of professional tooth-cleaning procedures per year (categorized into four groups: any professional tooth-cleaning, one professional tooth-cleaning, two professional tooth-cleanings, and more than two professional tooth-cleanings), waiting time between implant insertion and definitive prosthetic restoration, and peri-implant surgery were selected for the model.

After the proportionality assumption—that is, hazard ratios must be constantly associated with each

Table 5 A Cox Proportion Hazard Regression Model Stratified by Periodontal Surgery Showing the Effects of Five Variables on the Risk of Bone Loss

Variable	Coefficient	SE	Z test	*P* value	HR	95% CI
X_1 (connection type)	–0.71[a]	0.24	–2.98	.003	0.49	0.31–0.78
X_2 (cigarettes per day)	0.04	0.02	2.24	.025	1.04	1.00–1.07
X_3 (insertion torque)	0.23	0.03	6.83	< .001	1.26	1.18–1.35
X_4 (professional cleaning procedure per year)[b]	0.46	0.14	3.38	.001	1.58	1.21–2.06
X_5 (waiting time for definitive restoration)	–0.06	0.02	–2.98	.003	0.94	0.91–0.98

[a]The reference group was internal connection implant-abutment configuration.
[b]"Professional cleaning procedure per year" was categorized as: any professional tooth-cleaning, one professional tooth-cleaning, two professional tooth-cleanings, and more than two professional tooth-cleanings.
SE = standard error; HR = hazard ratio.

covariate over time— was checked, it was apparent that only the exposure surgery did not respect it (test of proportional-hazards assumption, $P = .0071$). Therefore, the model was adjusted stratifying by surgery. As a consequence of this, the baseline hazards for the three surgery groups (no peri-implant surgical treatment, surgical treatment simultaneously with and before implant insertion) were different. The log-rank test showed that when patients were treated with surgery simultaneously, the implant insertion had a more rapid bone loss than in the other two groups ($P = .0294$). In the Cox model, stratified by surgery, all exposures significantly influenced the development of bone loss (Table 5). Internal-connection implants had a higher hazard than external-connection implants (HR, 0.49; $P < .003$). Also, the number of cigarettes smoked per day (HR, 1.04; $P = .02$) and the amount of torque (HR, 1.26; $P < .001$) increased the hazard of bone loss. In the same way, the hazard increased as the number of professional tooth-cleaning procedures per year (HR, 1.58; $P = .001$) increased. The significance of these results was probably due to a higher number of professional treatments in patients classified by the prosthodontist as being at risk for periodontal disease. Moreover, an increase in the waiting time between implant insertion and definitive prosthetic restoration was protective against bone level reduction (HR, 0.94; $P = .003$).

DISCUSSION

This sample is a good overview of the patients treated by active AIOP members between January 2003 and December 2007. Of the respondents, 33% completed the spreadsheet with good quality data.

The sample population was comprised of more than 1,000 patients, with a higher number of female than male patients. However, sex did not influence the baseline and was not a risk factor for implant complications.

Patients were predominantly nonsmokers or low-smokers treated at least twice a year with professional tooth-cleaning. Implants were inserted primarily in the posterior area, eg, in molar and premolar sites, of the maxilla and mandible. The implant-abutment connection configuration was distributed equally between internal and external connections. In the sample, only 19.4% of implants were inserted with a torque below 25 Ncm; 55.9% of implants were inserted with a torque between 25 and 35 Ncm, and 24.7% above 35 Ncm. Most implants had a titanium abutment and, after a delayed screw load, were temporarily restored. Regenerative surgery was performed in 27% of cases only. The crowns were primarily cemented and had an extragingival margin with a tooth or a crown on the tooth or implant in the opposite arch.

The number of biologic or mechanical negative events was very low during the period of follow-up, with no difference between internal and external implant-abutment connection configurations. Only 16 (1.1%) in the implant sample had mechanical negative events because of implant/abutment/screw/connection structure damage. The numbers of unscrewed implants and of restoration fractures of the esthetic ceramic of metal-ceramic and of zirconia-ceramic crowns were also not clinically relevant, with no difference between internal and external implant-abutment connection configurations. This result is slightly different from conclusions achieved by a recent literature review in which the type of connection seemed to have an influence on the incidence of screw loosening, with more loose screws reported for externally connected implant systems.[59] It should be noted that all single crowns and all abutments were made by many different dental technicians, making comparison of the technical features of all these prosthetic appliances very difficult.

The peri-implant biologic problem that developed during the observation was mainly due to the reduction in peri-implant bone height (bone loss in excess of 0.2 mm/year: 4.7%), whereas cases of abscess or implant mobility were close to zero (0.5%). Analysis of bone loss in excess of 0.2 mm/year and its relationship with implant-abutment connection configurations gave a marginally significant difference in development time. In fact, the difference in event development was very low. The 5-year cumulative survival rate was slightly higher in the external (1.5%) than in the internal implant-abutment connection configuration group. Obviously, 1.5% is a result that is not clinically relevant, partly for the degree of difference but mainly for the generic definition of the outcome: bone loss in excess of 0.2 mm/year. This was exclusively a dichotomous variable defining the presence or absence of reduction in peri-implant bone levels and not a numerical quantity to evaluate the severity of the process. However, continuing the analysis into this outcome was considered relevant to obtain information about the peri-implant effect in the implant site.

The low number of negative events could raise doubts about the selection of the sample: a bias could not be excluded. However, the sample was a "healthy ideal sample": predominantly nonsmoker or low-smoker with a regularly scheduled professional tooth-cleaning procedure, treated with single implants in the majority of cases without regenerative surgery. The Cox regression model showed the negative influence of smoking on periodontal health: the negative influence intensified as the number of cigarettes increased. Also, the hazard of the internal-connection implant was two times higher than that of the external-connection implant. In addition, each increment in insertion torque worsened the amount of bone loss in a directly proportional way. In contrast, an increase in waiting time between implant insertion and screw load was protective for bone level preservation.

Moreover, supplementary and additional peri-implant surgery showed different effects on bone level. Bone loss amount was significantly higher around implants treated surgically at implant insertion compared with those treated at advanced stages. However, no information was available regarding the real amount of bone loss before implant insertion in patients previously treated. This is the reason why, in the statistical analysis, the sample was stratified by the corresponding surgery variable. As a consequence of this, any comparison can be performed, and any conclusion can be reached about the effect of surgery on the amount of bone loss.

In a "healthy sample," the cumulative effect of those risk factors was not relevant from a clinical point of view. However, in conditions that are not ideal, it could be an option to consider the torque needed or to postpone the screw load or to opt for a specific type of connection, to define the likelihood of implant survival and the prognosis for the patient. Unlike the external-hexagon connection, the internal-connection configurations adopted by different companies are not alike, and these differences might have a profound impact on the clinical outcomes and on the incidence of complications. Further studies should be performed to evaluate the different types of internal-connection implants. In addition, the quality and the quantity of bacteria living in the gap present between an implant with an internal or an external configuration and abutment and their effect on peri-implant tissues should be evaluated.

It should be noted that one of the limitations of this study was that many different implant brands were included in the sample. A comparison could be more appropriate only for implant types where external as well as internal connections are available.

CONCLUSIONS

Within the limitations of this study, it can be suggested that there is no difference in the clinical outcome of single restorations connected to internal- or external-connection implants.

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