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CLINICAL RESEARCH

Prospective clinical-radiological study of the survival and behavior of short implants

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ABSTRACT

Statement of problem. Short implants are a therapeutic alternative for edentulous patients with severe bone resorption. Differences in peri-implant bone loss and complications of short implants depending on the type of connection are unclear.

Purpose. The main purpose of this clinical study was to evaluate the survival rate after 2 years of the short implants in the Oxtein system (Proclinic). Secondary objectives were to compare implant survival, peri-implant bone loss, peri-implant mucosal status, and associated complications in internal hexagonal connection versus external hexagonal connection implants.

Material and methods. A randomized clinical trial was carried out in 14 patients with a mean age of 62.7 ±8.5 years, with a total of 61 Oxtein L35 and L6 Proclinic implants being placed at the Faculty of Dentistry. A descriptive analysis, simple binary logistic regression model using generalized estimating equations. and Kaplan-Meier survival analysis were carried out (α=.05).

Results. Implant survival was 85.2% (52/61). Failure of all implants occurred before prosthetic loading; bleeding after probing occurred in 28 implants, being greater among external connection implants (57.6%) *P*=.025. The presence of plaque appeared in 36 of the implants, without statistically significant differences between external connection (72.8%) and internal connection (60.0%) (*P*>.05). A total of 28 implants had at least 2 mm of keratinized mucosa, without statistically significant differences between external connection (63.6%) and internal connection (35.0%) *P*=.200. A total of 8 complications (13.1%) were recorded, including connection fractures, screw fracture, framework fracture, and buccal fenestrations.

Conclusions. Short implants are a therapeutic solution to more complex surgical techniques. However, as lower survival has been reported, the characteristics of the implants and operator experience are important factors for their success. (J Prosthet Dent xxxx;xxx:xxx-xxx)

Bone resorption after tooth extraction occurs during the first 3 months of tooth loss and continues for at least 2 years. In a vertical direction, it can reach 4.48 mm in multirooted teeth and 4.16 mm in single-root teeth, although it depends on factors such as the presence of infection, previous periodontal disease, trauma during extraction, number and thickness of cortices, and systemic factors such as degenerative bone pathologies.[1,2] Several surgical techniques are available to increase bone for rehabilitation with implant-supported prostheses.[3] However, bone augmentation techniques involve surgical risk, patient morbidity, and increased treatment time and cost. Short implants have

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Clinical Implications

Proclinic short implants should be placed by experienced operators to avoid failure and complications. Short internally connected implants seem more favorable. However, no statistically significant differences were detected, and the choice should be based on individual circumstances.

been developed as an alternative to more complex surgical techniques.[3] Initially, short implants were defined as those with a length of less than 11 mm,[3] although, currently, short implants are defined as less than 8 mm in length.[4] The advantages provided by short implants have increased their demand from patients and dentists.[5] Ideal characteristics have been established in the design, placement, and functionality of short implants.[6] Rough or bioactive implant surfaces with the largest possible diameter (minimum of 4 mm) have been reported to be associated with higher success rates.[7–9] The lower bone availability, the frequent presence of cortical bone, and less vascularization requires careful placement, avoiding heating the bone.[10] For primary stability, 2 to 3 mm of cortical bone should be used to achieve good anchorage of the implant.[9] The insertion torque should range between 30 and 65 Ncm, since higher torques can cause the loss of the crestal bone.[11] Splinting them to other implants favors their long-term function and survival.[9] Furthermore, whenever possible, axial loading of the masticatory forces is preferable to nonaxial loading to avoid functional overloads on the bone.[10,11] In the long term, the peri-implant mucosa, the periodontal and peri-implant health are of importance for the survival of the implants.[12]

Advantages of short implants compared with other surgical techniques include fewer interventions, shorter treatment time, and reduced morbidity, risks, and complications.[13] The main objective of the present study was to evaluate the survival rate of short implants over a period of 2 years. Secondary objectives were to compare implant survival, peri-implant bone loss, the clinical parameters of the peri-implant mucosa, and the complications that occurred with short internal hexagonal connection implants versus short external hexagonal connection implants. The null hypothesis was that no differences in short implants would be found depending on the type of connection.

MATERIAL AND METHODS

A randomized clinical study was carried out in accordance with the Declaration of Helsinki (World Medical Assembly) by following the STROBE GUIDE of 2009. The study protocol was approved by the Ethics Committee of the San Carlos Clinical Hospital of Madrid (15/484-E). Volunteers were enrolled between September 2018 and September 2020 at the Master of Oral Surgery and Implantology and by the Implant Prosthodontics program of the Faculty of Dentistry. The inclusion criteria were healthy patients (Category I and II of the American Society of Anesthesiologists), aged between 18 and 85 years,[14] with the absence of general medical conditions, a contraindication for dental implants,[15] and the absence of uncontrolled periodontal disease according to the criteria of the Classification of Periodontal and Peri-implant Diseases and Conditions of the 2017 World Workshop.[16] The available bone height was at least 8 mm in the mandible, allowing 6-mm implants to be placed, within a 2-mm safety distance of the inferior dental nerve or 6 mm in the maxilla. The available bone width was at least 7 mm for the installation of 5-mm implants or 6.25 mm for the 4.25-mm implants. The individuals had to accept participation in the study and had to sign the informed consent. The exclusion criteria were inability to place implants because of poor mouth opening or cooperation, drug or alcohol users, heavy smokers (>15 cigarettes per day), diagnosed parafunctions, lack of follow-up or records associated with patient noncompliance with indications or absence from review visits.

Consecutive participants were randomized using a software program (Excel; Microsoft Corp) to determine the placement of Oxtein L35 or Oxtein L6 implants (Proclinic). The implants were placed by a final year resident using a conventional technique[17] at an insertion torque between 15 Ncm and 45 Ncm in 2 surgical stages. Antibiotic, anti-inflammatory, and analgesic medication was prescribed with 0.12% chlorhexidine rinses twice daily for 10 days. The second stage was 3 months after placement. The prostheses were provided by residents using conventional open tray impressions and were fabricated in metal-ceramic (Cobalt-Chrome milled; Riosa) directly to the implant connection. The retention was based on clinical criteria according to the emergence of the implant.

Implant survival was defined as the implant being in place and stable, evaluated by manual testing. Implant survival rates were calculated from placement to the follow-up time of 2 years. Early implant failure was considered if it occurred before placement of the definitive prosthesis, or late failure if it occurred subsequently. The demographic information of patients and implant, type of antagonist to the implant, and presence of keratinized gingiva of at least 2 mm were recorded on the day of implant placement and at 3, 6, 12, and 24 months. A simplified hemorrhage index (0- absence of bleeding on probing (BOP); 1- presence of BOP) and a simplified calculus index, described in the Oral Health

Index-Simplified (OHI-S) classification (0- no calculus present; 1- supragingival calculus that covers no more than one third of the exposed tooth surface; 2- supragingival calculus that covers more than one third, but less than two thirds of the exposed tooth surface or presence of individual streaks of subgingival calculus around the cervical portion of the tooth, or both; 3- supragingival calculus covering more than two-thirds of the exposed tooth surface, or a continuous thick band of subgingival calculus around the cervical part of the tooth, or both) were assessed.

Periapical radiographs were made with a radiographic holder (Positioner type XCP; Bader) and digitally evaluated with a software program (ImageJ 1.43; National Institutes of Health) at a magnification of ×10 to ×15. The space between 2 implant threads was used to calibrate and determine the magnification. Peri-implant bone loss was calculated on the mesial and distal aspects of each implant by measuring the distance between the implant platform shoulder to the first bone to contact the implant at baseline and at 3, 6, 12, and 24 months (Figs. 1, 2).

Biological complications and peri-implant diseases were evaluated according to the Classification of Periodontal and Peri-implant Diseases and Conditions of the 2017 World Workshop.[16] Peri-implant mucositis was diagnosed as the presence of profuse BOP and/or suppuration on probing, an increase in probing depth, and absence of bone loss beyond changes in the level of the turbinate bone resulting from initial remodeling.[18] The appearance of peri-implantitis was considered in the presence of BOP and/or suppuration on probing, an increase in probing depth, and bone loss greater than changes in the level of the marginal bone (≥2 mm) from baseline.[17,18] Mechanical complications were recorded for the implant and the prosthetic component.

A sample size calculation was not carried out since, according to similar studies such as Guarnieri et al,[19] which included 30 implants, significant differences in the primary outcome (implant survival) were reported between the 2 treatment groups. Regarding the statistical power analysis, a post hoc estimate was obtained. The sample size of 61 independent implants provided 78.9% power with a 95% confidence interval to detect failure rates of 5% and 35% as significant by using the logistic regression model. However, the implants were not independent, and this power was corrected because of the 2-level data structure. Each participant had a mean of 4.36 implants and an intrasubject correlation CCI=0.5 (moderate) was assumed, leading to a correction coefficient D=2.67. Therefore, 61 dependent implants provide the same power as 23 independent implants: 31.5% under the same previous conditions. A descriptive analysis was carried out and the inferential analysis, simple binary logistic regression models, were estimated using generalized estimating equations (GEE) to explain the probability of failure and complications depending on the connection group. Unadjusted estimates of OR and 95% confidence intervals were obtained from the Wald Chi[2] statistic. The same analysis was extended to a multiple model for adjustment for the other independent factors. The previous methodology was expanded with the inclusion of the time factor for the clinical variables of BOP and plaque. For the study of

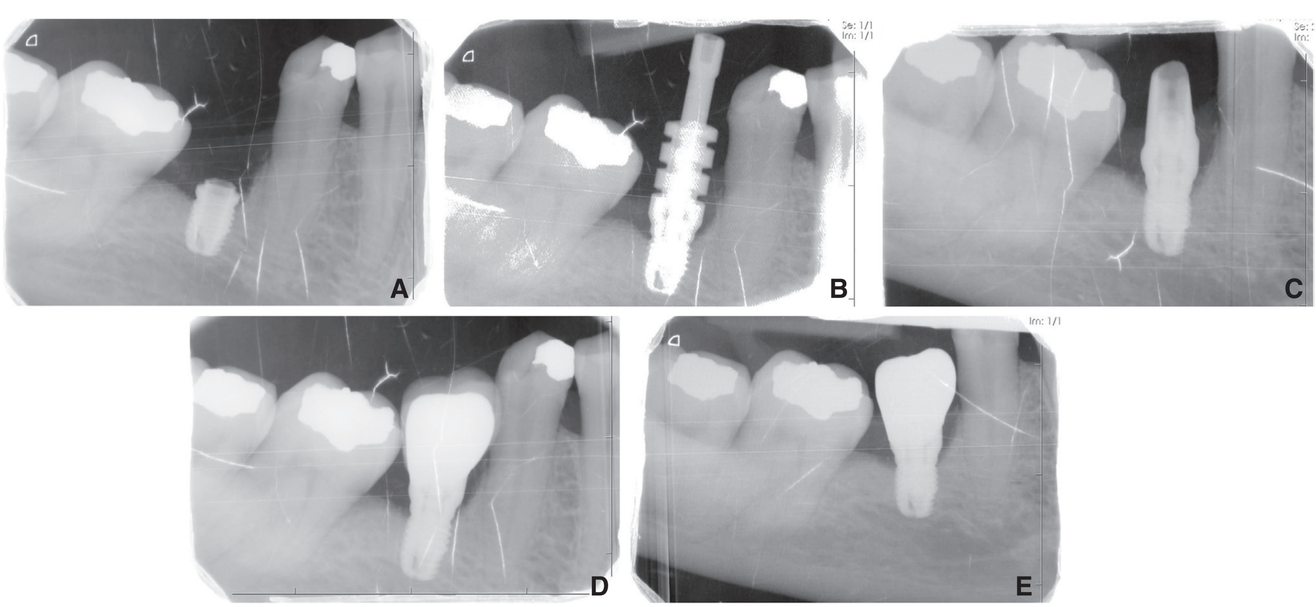

Figure 1. Radiographic images of representative short external connection implant. A, After implant placement. B, 3 months after implant placement. C, 6 months after implant placement. D, 12 months after implant placement. E, 24 months after implant placement.

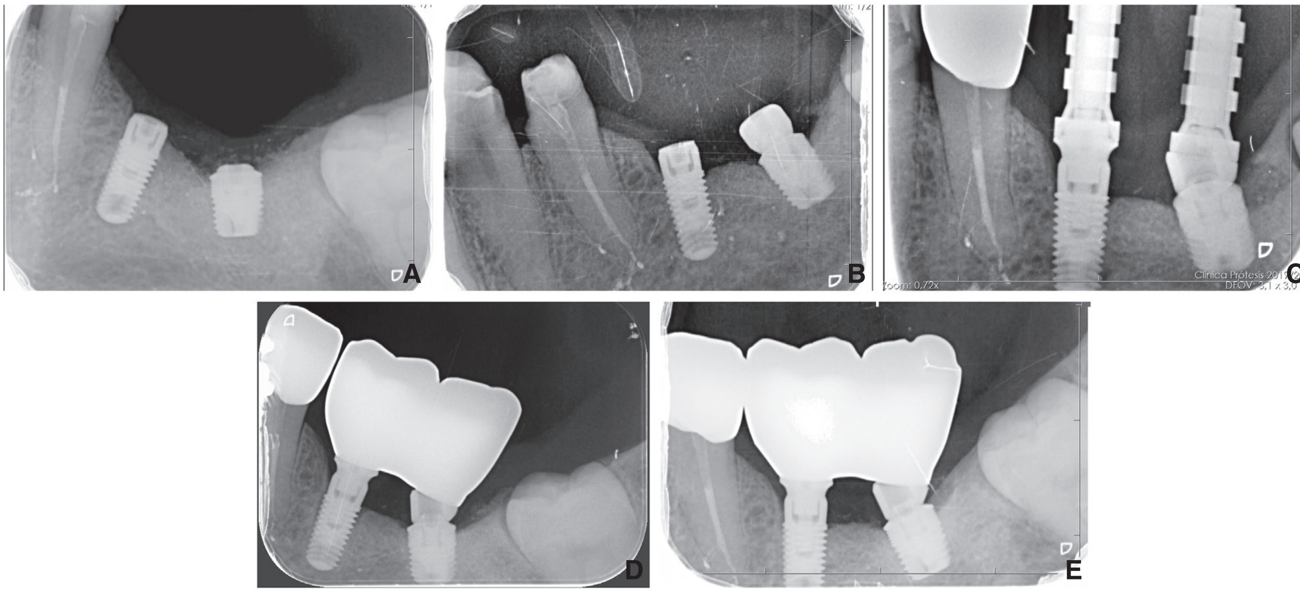

Figure 2. Radiographic images of 2 representative short internal connection implants. A, After implant placement. B, 3 months after implant placement. C, 6 months after implant placement. D, 12 months after implant placement. E, 24 months after implant placement.

peri-implant bone loss, a negative binomial distribution function was assumed with a GEE model and was justified by the intrasubject correlation inherent in the multilevel structure of the data. Multiple comparison tests were adjusted with the Bonferroni correction. At implant-level, time to event failure was analyzed using the Kaplan-Meier survival methodology. Cumulative survival functions were plotted and compared between groups using log-rank tests. Multilevel Cox regression frailty models for dependent observations were used to assess the relationship of survival with predictive variables. Hazard ratio estimations and corresponding 95% CI were obtained (α=.05). The data were collected on a spreadsheet (Excel; Microsoft Corp) and analyzed with a statistical software program (IBM SPSS Statistics, v28.0; IBM Corp).

RESULTS

Fourteen participants, (6 men and 8 women) with a mean ±standard deviation age of 62.7 ±8.5 years received 61 implants, 36 external connection (59%) and 25 internal connection (41%) (Table 1). More internal connection implants were placed in women (80%) and in molar sites (64%) compared with external connection implants (44.4%), and, in all participants, in the maxilla. Most (66.7%) of the external connection implants were placed in the mandible.

Table 1. Homogeneity of groups according to demographics, positional variables, and implant characteristics: Result of linear and logit model using generalized estimating equations (GEE)

	P
Sex	.003
Age	.049
Tooth	.078
Arch	.001
Diameter	.176
Antagonist	< .001

At the 24-month follow-up, the estimated survival rate was 85.2% (95% CI: 76.8 to 94.6%). At the final follow-up, survival was estimated at 80% (95% CI: 65.8 to 97.3%) in the internal connection group and 88.9% (95% CI: 79.2 to 99.8%) in the external connection group. The log-rank test showed homogeneity (P=.308). Implants in the female group showed a time-to-failure significantly lower than in the male group (HR =5.18; P< .001). All the failures were in the mandible (P< .001). No significant effect based on implant antagonist was found for time-to-failure (P=.052) or on the connection type (P=.353). In the multiple model evaluation, the arch was significant (P< .001). The presence of a band of keratinized mucosa of at least 2 mm was present in 35% of internal connection implants compared with 63.6% of external connection implants.

The progression of marginal bone loss was slightly higher in the external connection group. At 24 months (T4), 60.6% of the external connection implants developed loss compared with 50% of the internal connection implants (Fig. 3A). An increase in marginal bone loss was seen throughout the follow-up (P < .001), with a similar pattern (P =.355) and no differences between connections (P =.311) at any time (P =.355). The progression was greater in external connection implants, although both groups were stable after 1 year (T3) (Table 2). The loss was greater in men than women at visits T1 and T3. The posterior regions presented greater

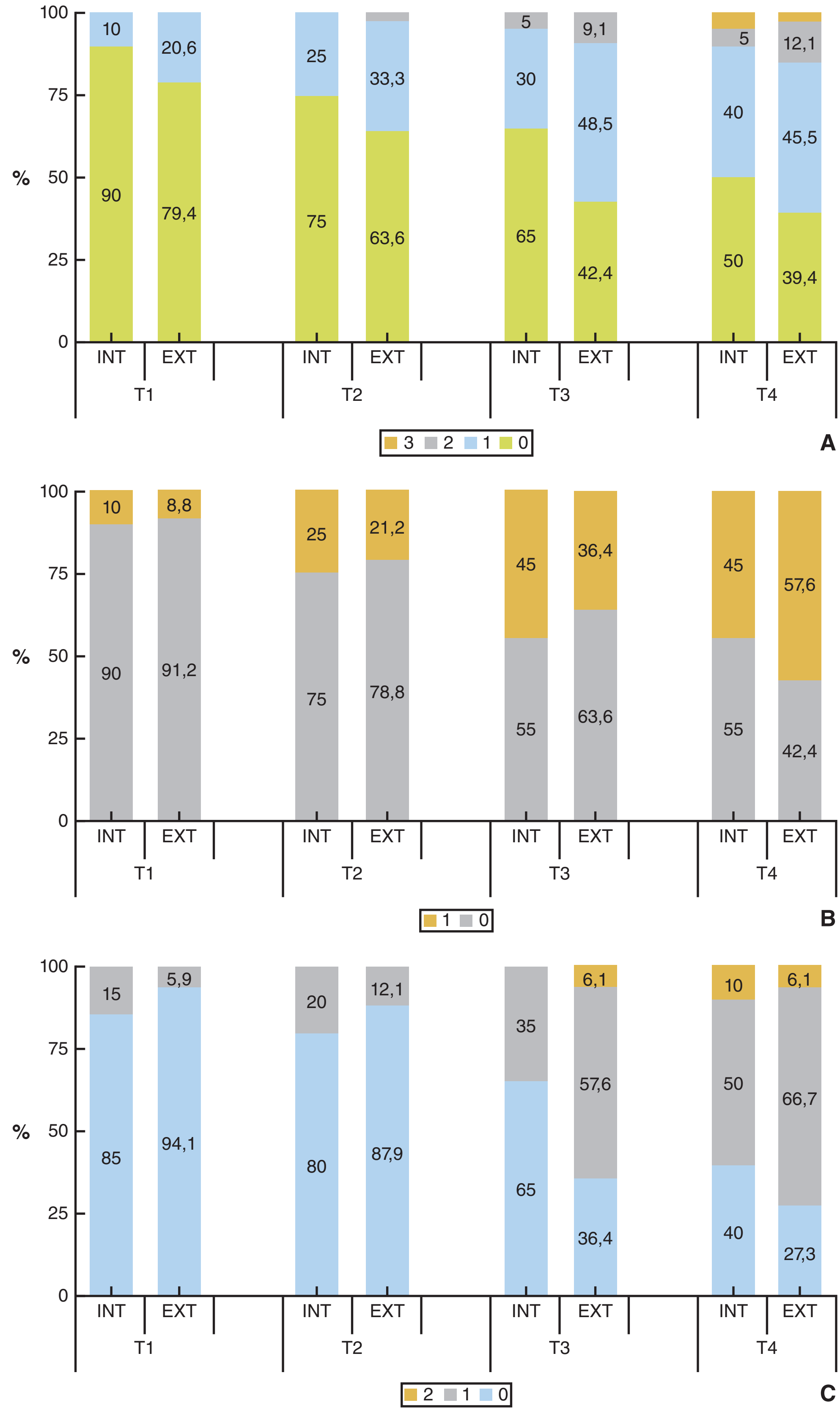

Figure 3. Result of regression model using generalized estimating equations (GEE) for negative binomial distribution function. A, Comparison of mean bone loss. B, Bleeding. C, Plaque. D,.

Table 2. Comparison of mean bone loss according to group. Result of multiple intragroup comparisons with Bonferroni correction

	INTERNAL	EXTERNAL
T1 versus T2	.275	>.999
T1 versus T3	.058	<.001
T1 versus T4	<.001	<.001
T2 versus T3	>.999	<.001
T2 versus T4	.020	<.001
T3 versus T4	.275	.254

Table 3. Comparison of mean bone loss according to group. Result of multiple regression model using generalized estimating equations (GEE) for negative binomial distribution function adjusted for other factors

	P
Time	<.001
Group	.545
Time per Group	.327
Sex	.005
Age	.287
Tooth	<.001
Arch	.970
Diameter	.007
Antagonist	.002

Table 4. Comparison of bleeding according to group. Result of multiple intragroup comparisons with Bonferroni correction

	INTERNAL	EXTERNAL
T1 versus T2	>.999	>.999
T1 versus T3	.098	>.999
T1 versus T4	.098	.007
T2 versus T3	>.999	>.999
T2 versus T4	>.999	<.001
T3 versus T4	>.999	.001

Table 5. Comparison of bleeding according to group. Result of multiple binary logistic regression model using generalized estimating equations (GEE) adjusted for other factors

	P
Time	<.001
Group	.025
Time by Group	<.001
Sex	.840
Age	.025
Tooth	<.001
Arch	.733
Diameter	.087
Antagonist	<.001

Table 6. Comparison of plaque according to group. Result of multiple intragroup comparisons with Bonferroni correction

	INTERNAL	EXTERNAL
T1 versus T2	>.999	>.999
T1 versus T3	.131	.016
T1 versus T4	.003	<.001
T2 versus T3	.887	.052
T2 versus T4	.104	<.001
T3 versus T4	>.999	>.999

Table 7. Comparison of plaque according to group. Result of multiple binary logistic regression model using generalized estimating equations (GEE) adjusted for other factors

	P
Time	<.001
Group	<.001
Time by Group	<.001
Sex	.867
Age	.332
Tooth	<.001
Arch	.265
Diameter	.805
Antagonist	.019

bone loss and smaller diameter implants registered greater bone loss progression (Table 3).

BOP increased by 20% from T3 to T4 in the external connection implants, while BOP remained stable in the internal connection implant group (Fig. 3B). The increase in BOP over time (P=.001) depended on the type of connection (P=.017). Differences in the prevalence of BOP in both groups were more evident at the 24-month visit (T4) (P=.017) (Table 4). External connection implants had a significantly higher 2-year BOP than at any previous visit. Age had a significant effect on the presence of BOP. Bleeding was more frequent in participants younger than 75 years. The premolar and molar positions had a higher frequency of BOP compared with the anterior positions. Natural teeth or crowns as antagonists showed BOP had significantly higher rates (P< .05) (Table 5).

The plaque index increased significantly in external implants from T2 to T3, while, in the internal implants, it increased more progressively (Fig. 3C) and significantly over time (P=.001). No differences were observed between connections (P=.97) at any visit (P=.155). The external connection implants were associated with more plaque than the internal connection implants (Table 6). A plaque prevalence of 88.9% and 74.1% was seen in premolars and molars respectively at the end of follow-up (Table 7).

A total of 9 failures (14.8%) were recorded. The rate was 20% among those with internal connections and 11.1% among those with external connections, and no statistically significant differences were found (P>.05) (Table 8). The failure of all implants occurred before prosthetic loading, 3 occurred intraoperatively, 2 after 7 days, and 4 at the second surgical stage. The estimated

Table 8. Failure according to group. Descriptive results of implant failure according to connection type

	GROUP					
	Total		INTERNAL		EXTERNAL	
	N	%	N	%	N	%
Total	61	100,0	25	100,0	36	100,0
NO	52	85,2	20	80,0	32	88,9
YES	9	14,8	5	20,0	4	11,1

Table 9. Failure according to group. Result of multiple binary logistic regression model using generalized estimating equations (GEE) adjusted for other factors

	P
Group	.376
Sex	.217
Age	.532
Tooth	.011
Arch	–
Diameter	.172
Antagonist	.657

Table 10. Complications according to group. Descriptive results of complications recorded according to connection type

	GROUP					
	Total		INTERNAL		EXTERNAL	
	N	%	N	%	N	%
Total	61	100,0	25	100,0	36	100,0
NO	53	86,9	22	88,0	31	86,1
YES	8	13,1	3	12,0	5	13,9

Table 11. Complications according to group. Result of multiple binary logistic regression model using generalized estimating equations (GEE) adjusted for other factors

	P
Group	.486
Sex	.452
Age	.220
Tooth	<.001
Arch	.073
Diameter	.088
Antagonist	.885

OR=0.5 (95% CI: 0.11 to 2.28) determined that, although the risk of failure was less with external connections, there was insufficient evidence of an effect (*P*=.37). A failure rate of 20% was observed in the anterior region and 18.8% in molars, but only 5.3% in premolars. The chi squared test suggests a certain association (*P*=.011) (Table 9). A total of 8 complications (13.1%) were recorded, 12% in the internal connection group and 13.9% in the external connection group (Table 10). The intraoperative mechanical complications were 2 connection fractures, 1 screw fracture, and 1 framework fracture. In the first 3, the failure of the implant was considered, since it was removed. Surgical complications were 3 buccal cortical dehiscences and a sinus perforation (OR=1.18 [95% CI: 0.17 to 8.12]). The prevalence of complications shows a dependence on the tooth form, with rates of 15% in premolars and molars compared with none in anterior teeth (Table 11).

DISCUSSION

The null hypothesis that no differences in short implants would be found depending on the type of connection was partially rejected. External connection implants were more associated with increased plaque index and BOP than internal connection implants.

Considering implant survival, short implants have been associated with higher failure rates than standard length implants.[2] According to some studies, the highest percentage of failures was explained by the use of machined surfaces that provide slower osseointegration with a smaller bone-implant contact surface.[7] Despite the initial results, subsequent studies obtained similar survival rates to those of conventional implants.[5] Short implants reduce morbidity in situations in which poor bone availability requires additional surgery, motivating studies on the safety of short implants as an alternative to complex surgical techniques.[2,17] Most studies reported that osseointegration failures were associated with atrophic jaws, in which bone quality was type III or IV, according to the Lekholm and Zarb classification.[17]

Of the 6 implant losses in the present study, 4 were intraoperative. Losses can be explained by the sensitivity of the technique, in which the limited bone availability requires precise drilling. The lost implants were in both the mandible and the maxilla, indicating that all types of bone quality require precise milling to achieve primary implant stability.[8] The widest possible diameter should be used, as the increase in the surface of the implant reduces the tension at the bone level in the 2 coronal threads of the implant.[11] Furthermore, splinted implants have been recommended to minimize the prosthesis screw load and implant fracture and to improve load distribution at the bone level.[11,12] Anitua et al[12] reported that short implants should always be placed in 2 surgical stages regardless of insertion torque and primary stability, justified by an initial overload of the first 2 mm of cortical bone, leading to ischemia and bone loss. Other authors have recommended extended osseointegration times, for example, Pieri et al,[20] who proposed waiting 5 to 6 months before loading. However, lengthening the osseointegration period was not associated with improved survival rates, since they recorded 2 losses of the 61 short implants placed.

Anitua et al.[21] reported that the mean ±standard deviation vertical space rehabilitated was 17.05 ±3.05 mm, finding a proportional relationship between a greater prosthetic space with greater peri-implant bone loss during the first year. Furthermore, they reported the greatest bone loss of short implants occurred when opposing removable partial dentures (1.28 ±1.09 mm), followed by complete dentures (0.89 ±0.6 mm) and the natural dentition (0.73 ±0.6 mm).

The sample size was different regarding the implant connection. Analyzing the bone loss differences, 65.2% were found in external connection compared with 30.7% in internal connection of the implants. There was 0.95 mm of crestal bone loss in the external connection versus 0.85 mm in the internal connection, with standard deviations of 0.97 and 0.5, respectively. Espósito et al[22] reported no statistically significant differences in terms of bone loss or implant failure according to the type of connection during the first year. Hagiwara et al[10] reported better results and preferences with the internal connection, due to the professional's better sense of surgical and prosthetic security.

The presence of plaque and BOP was found in 91.3% and 60.8% of external connection implants compared with 46.1% and 38.4% of internal connection implants, respectively. The authors are unaware of studies that analyzed BOP parameters according to the type of connection, although connection type has been reported to be directly related to the presence of plaque, and, therefore, to the inflammation of the peri-implant mucosa.[23] Differences in the presence of keratinized mucosa according to the connection could have produced a selection bias that may have influenced the results. Differences in percentages were found in favor of internal connection implants. Larger studies in terms of sample size would be necessary to establish statistically significant relationships and results. Limitations of this study included the small sample size that restricted the statistical analysis and significance of the results. Furthermore, the follow-up time should be expanded to at least 5 years to determine long-term relationships.

CONCLUSIONS

Based on the findings of this randomized clinical trial, the following conclusions were drawn:

1. A failure rate of 14.8% was found in the total sample, 20% with internal connections and 11.1% with external connections.
2. Short implants were found to be a therapeutic solution for the prosthetic rehabilitation of edentulous patients with difficulties undergoing more complex surgical techniques.
3. Difficulties were encountered in achieving primary stability in surgery due to the implant length and the need for precise milling.
4. The internal and external connection implants had statistically similar performance, although this finding may have been associated with the small sample size.

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