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Screw-retained internal connection zirconia CAD–CAM abutments in single implant reconstructions: Results of a 1-year prospective case series study

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Abstract

Purpose: To evaluate the clinical and radiographic outcomes of single-tooth implant restorations using one-piece, internally connected, screw-retained, computer-aided design and computer-aided manufactured monolithic zirconia restorations fabricated on regular diameter implants.

Material and methods: Following a 2-stage surgical procedure, 22 implants placed in anterior and posterior areas in 21 partially edentulous patients (mean age of 55 years; 9 males/12 females) were evaluated in terms of plaque index, pocket probing depth, bleeding on probing, level of oral hygiene (OH), signs of mucositis/peri-implantitis, esthetic score (ES), gingival zenith position (GZP), papilla index score, the thickness of peri-implant gingiva, radiographic marginal bone loss, and technical complications. Implants and restorations were prospectively followed from the insertion of the restoration (baseline), up to 12-months post-loading.

Results: A 100% implant survival rate resulted after loading; one implant was lost before loading. Clinically, patients performed an adequate OH, and tissues were kept healthy. Probing depth showed a slightly lower value at baseline compared to any follow-up examination (2.26 [0.94] at baseline vs. 2.53 [0.66] mm at 12 months). ES, GZP, and the thickness of the peri-implant gingiva improved throughout the course of the study. Radiographically, average marginal bone level (MBL) was 0.40 (0.40) mm after 1-year follow-up with no differences in average MBL at all time points. Technically, after 1 year of clinical function, neither abutment fracture nor any other serious complications occurred. Hence, prosthetic reconstruction survival rate was 100%.

Conclusions: Clinical outcomes of single-tooth implant restorations using internally connected, screw-retained, computer-aided design and computer-aided manufacturing monolithic zirconia abutments can be considered a reliable treatment alternative after 1-year clinical observation.

KEYWORDS
dental implant, esthetics, marginal bone level, monolithic, outcomes, single implant restorations

Survival rates of single-implant-supported reconstructions range between 89% and 94% at 10 years[1,2] and, therefore, are considered a well-established alternative to conventional three-unit fixed dental prosthesis in all areas of the jaws. However, single implant reconstructions can be clinically challenging, especially in the esthetic zone. Factors, such as type of implant–abutment connection,[3] abutment material fatigue strength, biocompatibility, machinability, and chemical stability,[4] three-dimensional (3D) implant position,[5] functional and esthetic requirements of the planned restoration,[6] soft tissue thickness and translucency,[7] crown-to-implant ratio,[8] or tooth location[9,10] among others, have been suggested to influence implant-supported single-tooth restorations' clinical outcomes.

Titanium is the preferred material for custom implant abutment fabrication.[11] However, the use of metal abutments

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has important esthetic limitations due to the possible soft tissue grayish discoloration, especially with thin overlying mucosal tissues.[12–14] Due to their natural appearance and peri-implant soft-tissue color integration when compared to metal abutments, zirconia abutments and zirconia abutments reinforced with secondary metallic coupling have been recommended to overcome the esthetic limitations of metal abutments.[15] In addition, zirconia ceramic has demonstrated favorable properties, such as high biocompatibility,[16] less bacterial adhesion,[17] no corrosion and/or galvanic coupling, and superior mechanical strength when compared to other dental ceramics.[18]

Although most of the existing literature on single implants restored with zirconia abutments use cemented all-ceramic restorations[19] and although screw-retained restorations seem to be preferred by clinicians due to an absence of a cement interface and ease of fabrication and retrievability, only a few clinical studies report on screw-retained restorations using zirconia abutments.[20,21]

In the last decade, digital technology has gained increased attention from clinicians and researchers due to the development of restorative materials and their clinical applications. The influence of prosthetic implant abutment design and fabrication process on mechanical, biological, and esthetic clinical outcomes of CAD–CAM abutments has been recently analyzed in a systematic review,[22] and results indicate that CAD–CAM abutments have overall good success and survival rates and provide very similar clinical outcomes when compared with conventional abutments.

More recently, considering the advantages of CAD–CAM technology used in conjunction with screw-retained restorations, custom zirconia screw-retained abutments have been suggested as an alternative to cement-retained, implant-supported single-tooth restorations.[21] This restorative option enables zirconia abutments to be directly veneered. As a prerequisite, implant placement and final restoration design must be planned carefully following a prosthetically driven concept. This way, the zirconia framework can be designed with an anatomical foundation to support the veneering ceramic, thus reducing the risks of chipping/fracture due to inadequately supported veneering ceramic.

In vitro studies have demonstrated that internally connected implant–abutment design configurations provide higher abutment stability, reduce fatigue fracture and screw loosening, as well as reduce stresses transferred to the crestal bone when compared to external butt joint interfaces.[23] However, in vitro investigations evaluating different implant systems have raised concerns when zirconia is used as abutment material, especially with internally connected implant–abutment designs, due to the brittle nature and risk of fracture of the interlocking portion of high-strength polycrystalline zirconia ceramic abutments.[24,25]

The number of clinical investigations using zirconia abutments is still limited. Most clinical investigations are based on CAD–CAM zirconia abutments with external butt–joint interface,[26,27] and only a small number of clinical investigations have been published using one-piece internally connected CAD–CAM zirconia reconstructions.[20,21,28] Therefore, the objective of this prospective clinical follow-up investigation was to evaluate the clinical performance, survival, as well as the biological, esthetic, and technical complications (TCs) of single-tooth implant restorations using internally connected, screw-retained, CAD–CAM monolithic zirconia restorations fabricated on regular diameter implants. The initial hypothesis was that changes over time in clinical or radiographical parameters would not be statistically significant.

MATERIALS AND METHODS

The study protocol was approved by the Ethics Committee Review Board of the University of Granada (Ref. 918-2014) as a multicenter prospective case series study. Patients were consecutively recruited at the Department of Oral Surgery and Implant Dentistry, School of Dentistry, University of Granada, and at private clinics in Granada and Alicante, Spain, between June 2015 and April 2019. Subjects in need of a single-implant-supported restoration in anterior and posterior regions were included in the study. Prior to being included in the study, patients were informed of its purpose, and, after acceptance to participate, informed written consent was obtained from all subjects.

The inclusion criteria were partially edentulous patients missing one single tooth in the area of treatment, 18 years or older, successfully osseointegrated implants, no active systemic disease, and smoking ≤10 cigarettes/day. Only patients with an American Society of Anesthesiologists Status I or II were included.[29] Exclusion criteria included subjects with uncontrolled/untreated periodontal disease, patients requiring hard/soft tissue augmentation, severe bruxism, and poor compliance with oral hygiene (OH).

In the present study, success was defined by the percentage of restorations that remained in situ without any modifications, whereas survival was defined by the percentage of restorations that remained in situ with or without modifications; on the other hand, failure was defined by the percentage of restorations that needed to be replaced.[30]

Straight threaded, tapered apex, and internally connection implants (OsseoSpeed EV, Astra Tech Implant System, Dentsply Sirona Implants, Mölndal, Sweden) were placed by specialists in periodontology and oral surgery in the study centers and included standard diameter (3.6/4.2 mm) implants depending on the available mesiodistal interdental space and buccolingual bone volume of the receptor site. All implants were installed in healed alveolar ridges following a 2-stage surgical procedure using a surgical guide based on a pretreatment diagnostic wax-up. After a 3-month osseointegration period, a second-stage surgical procedure was performed and transmucosal healing abutments were connected. Two weeks were allowed for soft tissue healing before a final impression was made.

Disposable plastic stock trays and polyether impression material (Permadyne Penta, 3M Espe AG, Seefeld, Germany)

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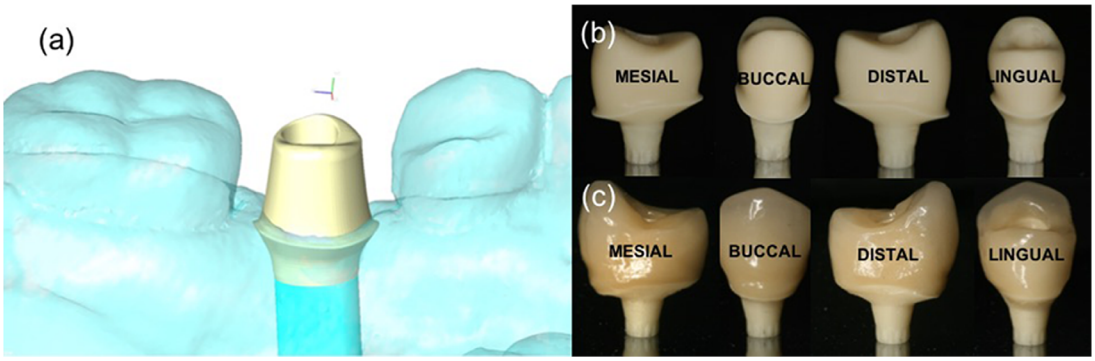

FIGURE 1 (a) Zirconia abutments were virtually designed based on the patient's individual restorative requirements; (b) mesial, buccal, distal, and lingual views of screw-retained yttrium oxide partially stabilized tetragonal polycrystalline zirconia (Y-TZP) abutment substructure after manufacturing; (c) zirconia abutment completed after veneering ceramic application.

were used to make implant-level, pick-up impressions. New impression copings were employed for each intraoral impression to avoid mechanical errors due to rotational freedom and/or mismatching between implant/prosthetic components. Prior to impression pouring, Gingifast soft tissue material (Zhermack Spa, Italy) was used to replicate soft tissue areas adjacent to implant analogs. Impressions were then poured with improved Type IV die stone (GC Fuji Rock, GC Europe, Leuven, Belgium).

Titanium, implant level, temporary cylinders (Temporary Abutment EV, Dentsply Sirona Implants, Mölndal, Sweden) were used to fabricate a full-contour, screw-retained, diagnostic wax-up according to the anatomical requirements of each patient. Diagnostic casts and wax-ups were then scanned. A design software (Atlantis Virtual Abutment Design Software, Dentsply-Sirona Inc.) was used to custom design each individual zirconia abutment substructure. After design approval by investigators in each study center, custom, implant-supported, CAD–CAM screw-retained yttrium oxide partially stabilized tetragonal polycrystalline zirconia (Y-TZP) abutments (Atlantis Crown Abutment, Dentsply Sirona Implants, Mölndal, Sweden) were fabricated. Zirconia substructures were then sent to the research centers for clinical try-in. After clinical and radiographic verification of precision of fit, zirconia abutments were sent to the reference laboratories for veneering ceramic application using a hand build-up veneering ceramic technique. Each of the two laboratories used its preferred brand of veneering ceramic (Figure 1). Once completed, abutments were returned to each study center for final insertion. Prior to screw tightening, restorations were evaluated clinically and radiographically to ensure the precision of fit (Figure 2). Abutment screws were then tightened to 25 Ncm following the manufacturer's recommendations, and screw access channels were sealed with polytetrafluoroethylene tape and tooth-colored composite resin material.

Clinical evaluation was performed using magnifying glasses (magnification of 3.5×) and consisted of biological parameters, esthetic and radiographic outcomes as well as TCs recorded at baseline and at 3, 6, 9, and 12 months.

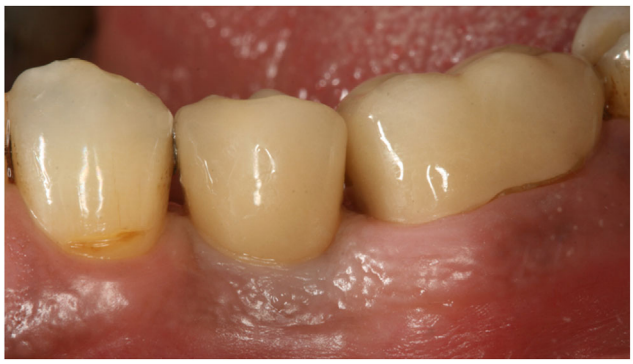

FIGURE 2 Lateral view of screw-retained zirconia abutment after clinical insertion.

Biological parameters included (1) plaque index (PI)[31] that was assessed using a 4-point scale (0 = no plaque, 1 = detectable plaque present upon probing, 2 = moderate plaque present upon probing, 3 = 1–2 mm thick plaque present in vestibular and interproximal spaces), (2) probing pocket depth (PPD) measured in the implant restorations, from the mucosal/gingival margin to the bottom of the probeable pocket using a periodontal probe to nearest 0.5 mm at four sites of the restoration (mesial, distal, buccal, and lingual), (3) bleeding on probing (BoP) was assessed as absent = 0 and present = 1, in the restoration and in the adjacent mesial and distal teeth, (4) level of OH, determined by the examiners according to a four-point scale (1 = excellent, 2 = good, 3 = poor, and 4 = very poor), and (5) signs of mucositis/peri-implantitis (Ms/Ps).[32] Mucositis was defined as probing depth ≥4 mm and BoP, and peri-implantitis was diagnosed if bone loss ≥1.8 mm or three implant threads after 1 year was also present.

Esthetic outcome was analyzed by investigators at each study center using four parameters that included a 4-point esthetic score (ES) defined as 1 = excellent, 2 = good, 3 = poor, and 4 = very poor; an evaluation of the gingival zenith position (GZP), assessed by measuring from the most apical aspect of the buccal–gingival restorative margin to the incisal edge of the prosthetic crown, using a

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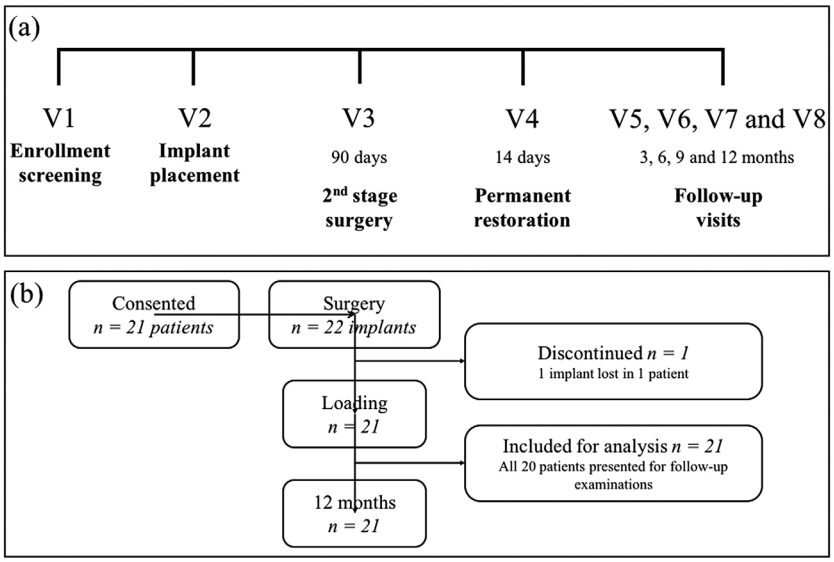

FIGURE 3 (a) Overview of the study sequence and (b) diagram of screening and follow-up.

TABLE 1 Overall study data

Number of patients	20 patients for final examination
Mean age	55
Sex	
Male	9
Female	11
Number of implants	21
Implant Position (*n* [%])	
Incisor	3 (14.29%)
12	1 (4.76%)
22	2 (9.52%)
Premolar	13 (61.90%)
14	5 (23.81%)
25	2 (9.52%)
35	4 (19.05%)
45	1 (4.76%)
Molar	5 (23.81%)
36	2 (9.52%)
46	3 (14.29%)

periodontal probe to the nearest 0.5 mm; an assessment of the height of mesial and distal papilla performed using the papilla index score (PIS) (0 = no papilla, 1 = less than half of papilla present, 2 = half of papilla present, 3 = papilla completely fills interproximal space, and 4 = interproximal hyperplastic tissue present).[33] Finally, the thickness of the peri-implant keratinized gingiva (TKG) was assessed 1 mm below the mucosal/gingival margin, using an endodontic file and a rubber stop (# 20 endodontic K-file, Dentsply Maillefer, Switzerland) to measure the distance from the outer surface of the attached gingiva to the underlying alveolar bone.

TC evaluation consisted of recording data on the wear of the veneering porcelain (no wear, small facet, or marked facet) abutment fracture, abutment screw loosening/fracture, veneering porcelain chipping/fracture, and/or tattooing of the gingival tissues.

Intraoral radiographs were made using the long-cone paralleling technique with a film holder (Rinn, Dentsply Sirona Inc.). Care was taken to ensure a clear image of the threads on both sides along the implant body. Bone levels around both implants and adjacent teeth were measured by an experienced independent radiologist (University of Gothenburg) considering either the implant shoulder or the cementoenamel junction as a reference point, respectively. These measures were obtained both at the mesial and distal sides. Bone level change with respect to restoration delivery was also calculated for each measurement at each of the subsequent time points. Additionally, the distances from the implant to the anterior and posterior adjacent teeth were measured at the time of implant placement.

For radiographic analysis, all radiographs were displayed in software (Illustrator CS; Adobe Systems Inc, San Jose, CA, USA) on a 24-in. LCD screen (iMac, Apple Inc, Cupertino, CA, USA). The screen resolution was 1920 × 1200 pixels. The measuring tool of the software was used to make the measurement, taking the magnification into account. The magnification was calculated by measuring the implant diameter displayed on the screen divided by the actual diameter of the implant.

Marginal bone level (MBL) was determined by measuring the distance between the implant shoulder and the marginal bone-to-implant contact at the mesial and distal aspects of each implant. Bone level was presented as the mean value for distal and mesial surfaces at each time point. All measurements were made to the nearest 0.1 mm.

Statistical analysis

Categorical data are presented as absolute values and the respective percentages, whereas continuous variables are

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described as mean and standard deviation. For each variable, a descriptive analysis has been performed. In addition, data was incorporated into an IBM SPSS Statistics 26 (release 26.0.0.2) file in order to proceed with the statistical analyses. Differences over time in continuous variables were evaluated with Related-Samples Friedman's Two-Way Analysis of Variance by Ranks, followed by the post hoc Bonferroni correction for multiple comparisons if pair-wise evaluation was conducted. When two related measures were compared, the Related-Samples Wilcoxon signed-rank test was used. We explored the correlation between different variables and the main outcome variable of the study by using a Pearson correlation test. Finally, the correlation between categorical variables was evaluated by Cramèr's V test. Microsoft Excel for Mac OS X (version 16.16.27) was used for creating the graphs representing the data. In all cases, values of p below 0.05 were considered statistically significant. The present manuscript has been conducted according to the STROBE Guidelines for reporting observational studies.

RESULTS

A summary of study visits and patients included at each study landmark is presented in Figure 3. A total of 22 implants were installed in a total of 21 patients (9 males and 12 females, with a mean age of 55 years); however, one implant failed during osseointegration. Consequently, the patient was excluded from subsequent follow-up evaluation. Therefore, a total of 20 patients and 21 implants were finally included in the study at the insertion of the restoration (baseline). Of the remaining 20 patients, 1 patient received 2 implants. All 20 patients attended the scheduled follow-up examinations. Two of the authors (RC and LG-G), one at each study center, performed all the clinical and radiographic examinations at the insertion of the restoration, and at 3-, 6-, 9-, and 12-month post-loading. A total of 21 implants and their corresponding 21 screw-retained, zirconia, single-implant-supported reconstructions remained in situ throughout the observation period with no major complications. The implants on the test sites were used to replace 10 single missing teeth in the maxilla and 11 in the mandible, which accounted for 13 premolars (61.90%), 5 molars (23.81%), and 3 incisors (14.29%) (Table 1).

After loading, all implants included in the study at baseline maintained successful osseointegration for the follow-up time of the study, resulting in a 100% implant survival rate. No biologic complications (clinical signs of mucositis/peri-implantitis) occurred during the follow-up period. In general, patients performed an adequate OH, and tissues were kept healthy as determined by both the PI and OH Index (Figure S1). The level of OH was determined to be "Excellent" or "Good" through the observation period with only one patient (4.8%) showing poor OH at some of the visits; no patient was categorized as performing "Very poor" OH. Regarding PI, although a "No plaque" level was detected in 61.9% of the patients at baseline, this percentage increased to 81% of patients after 3 months. PI was maintained at that level through the rest of the evaluation period. No patient had either moderate or abundant plaque, except for one of them at the 12-month visit. BOP (Figure S2) was relatively frequent, both at the mesial and distal teeth as well as the implants. Regardless, no clear pattern of correlation was observed between BOP on the mesial or distal teeth and the implant (Cramer's V test).

PPD (Figure S3) was measured only around the implant reconstructions. At baseline, the average PPD of 2.26 (0.94) mm was slightly lower than at any follow-up examination of 2.53 (0.66) mm. These differences were not statistically significant ($p = 0.115$, Related-Samples Friedman's Two-Way Analysis of Variance by Ranks).

At baseline, a PIS of 0–1 (no papilla/<50%) was detected in around 90% of both mesial and distal sites. In turn, at the 12-month examination, PIS of 2 or 3 (>50%/full papilla) accounted for approximately 50% of the cases (Figure 4). As could have been expected, the PIS in the mesial and distal sides were significantly associated with one another, except at the initial time points ($p < 0.05$, Cramèr's V test).

The ES data indicated that although at baseline only 28.6% of restorations were considered "Excellent," this increased to 52.4% at 12 months. This change from baseline to 1-year follow-up was statistically significant ($p < 0.001$, Cramèr's V test). Note that only one case was considered "Poor" at baseline and another one as "Very poor" throughout the course of the study (Figure 5).

The analysis of the GZP position indicates a change from baseline (8.24 [1.38] mm) to the 12-month follow-up (7.90 [1.45] mm) (Figure 6). The statistical analysis of the changes over time showed overall significant differences ($p = 0.003$; Related-Samples Friedman's Two-Way Analysis of variance by Ranks). However, with the Bonferroni correction for multiple comparisons, no statistically significant differences in the pair-wise comparisons between time points were found.

Finally, there were changes in the TKG over time (Figure 7): although at baseline, the mean TKG was 2.81 (0.78) mm; at the 12-month examination, TKG increased to 3.21 (0.93) mm. As for the GZP, the overall differences over time were statistically significant ($p = 0.008$, Related-Samples Friedman's Two-Way Analysis of Variance by Ranks), but no pair-wise significant differences were found when applying the Bonferroni correction for multiple comparisons.

After 1 year of clinical function, no abutment fracture occurred. Abutment screw loosening was observed in one patient at the 3-month follow-up visit. The screw was retightened at the same clinical visit without further complications. Hence, prosthetic reconstruction survival rate was 100%. Loosening of all or part of the composite resin-based filling sealing the screw access channel was detected in four patients at 3-months and in one patient at the 6-month follow-up visit. A small wear facet on occlusal porcelain was observed at the 3-month evaluation in another patient (Table 2).

Radiographic data is presented in detail in Table S1. First, a comparison was made between mesial and distal sides of

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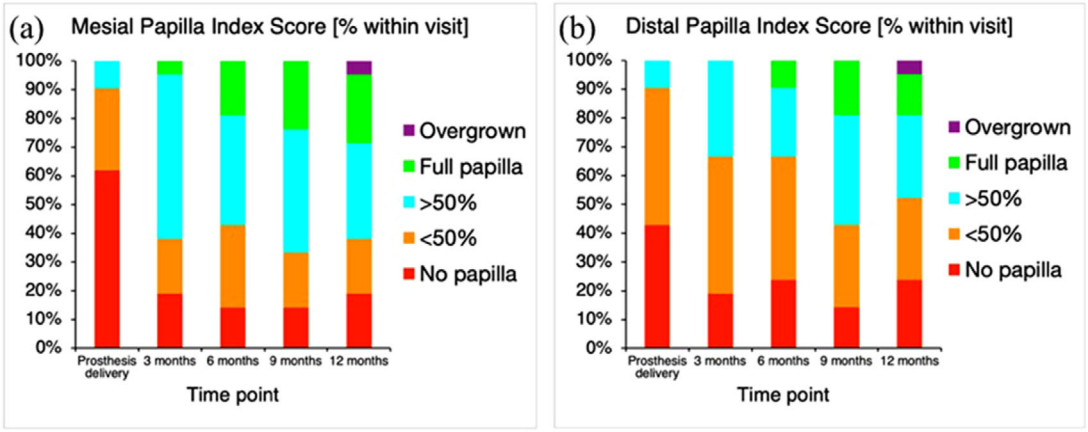

FIGURE 4 Graphical representation of the (a) mesial and (b) distal papilla index over time.

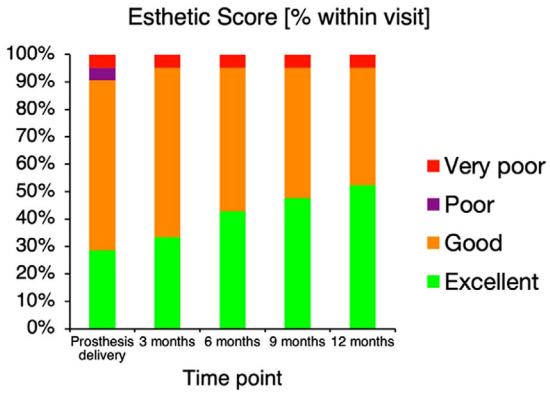

FIGURE 5 Graphical representation of the esthetic score over time.

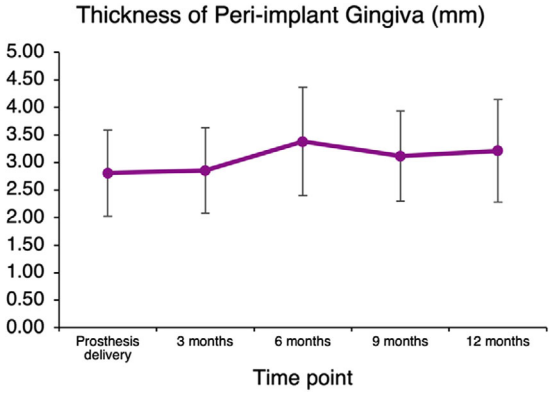

FIGURE 7 Graphical representation of the thickness of peri-implant gingiva over time.

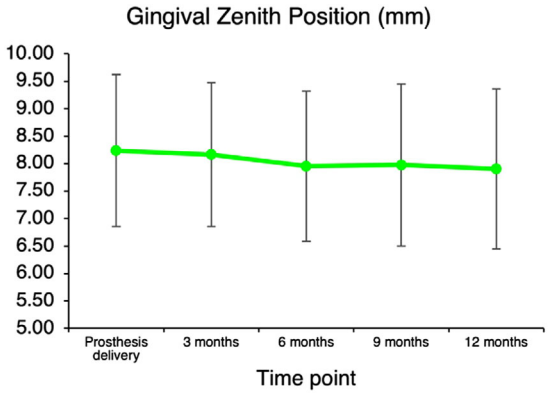

FIGURE 6 Graphical representation of the gingival zenith position over time.

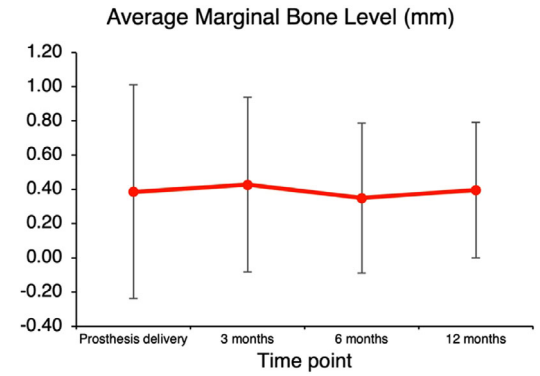

FIGURE 8 Graphical representation of the distal and mesial averages of implant marginal bone level (MBL) over time.

the implant at each time point. No differences were observed, so it was decided to use the average mesial and distal MBL for further analyses.

No differences were detected in average MBL when evaluating all time points ($p = 0.837$, Related-Samples Friedman's Two-Way Analysis of Variance by Ranks) (Figure 8). Thus, no post hoc analysis was conducted. In fact, the magnitude of change between baseline and the remaining follow-up visits was around 0 in all cases.

Regarding the bone level in the anterior and posterior teeth, no differences were detected from "Prosthesis delivery" to "12 months" ($p = 0.605$ and $p = 0.147$; Related-Samples Wilcoxon Signed Rank Test) or in anterior and posterior teeth.

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TABLE 2 Technical complication study data

Technical complications (*n* [%])				
	No	Loss of composite covering the screw-access hole	Slight wear of occlusal porcelain without chipping	Screw loosening
Restoration delivery	21 (100%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
3 months	16 (76.2%)	4 (19.0%)	1 (4.8%)	1 (4.8 %)
6 months	19 (90.5%)	1 (4.8%)	1 (4.8%)	0 (0.0%)
9 months	21 (100%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
12 months	21 (100%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Finally, no significant correlation was found between any of the MBL measures on the adjacent teeth and the implant MBL measures nor magnitudes of MBL change, except for the distance between the implant and the posterior tooth. In this last case, it was detected that the higher the distance, the higher the bone loss on the distal side of the implant at every time point (Pearson correlation = 0.471, $p = 0.031$ at "Prosthesis delivery"; Pearson correlation = 0.473, $p = 0.035$ at "3 months"; Pearson correlation = 0.648, $p = 0.003$ at "6 months"; Pearson correlation = 0.499, $p = 0.025$ at "12 months").

DISCUSSION

The differential aspect of the present research is the use of one-piece, screw-retained, internally connected, computer-aided design and computer-aided manufactured zirconia restorations fabricated on regular diameter implants. The number of clinical investigations evaluating this type of connection and prosthesis design is scarce[20,21,34,35]; therefore, the purpose of this research was to evaluate the clinical, radiologic, esthetic, and technical outcomes throughout a 1-year observation period.

After 1-year follow-up, the main outcomes of the current study included radiological bone stability, with no marginal bone loss (0.39 [0.63] vs. 0.40 [0.40] mm from prosthesis delivery to 1-year follow-up, respectively), an increase of mucosal thickness (2.81 [0.78] vs. 3.21 [0.93] mm from prosthesis delivery to 1-year follow-up, respectively), and an improvement of the ESs (52.4% and 42.9% of restorations classified as "Excellent" or "Good", respectively). Moreover, no severe TCs were appreciated.

In the current investigation, the implant–abutment connection was characterized by an internal indexed–conical connection, which can play an important role from different points of view. Biologically, the type of connection could promote different patterns of marginal bone loss and consecutively many other biological events. Although the Camlog Foundation Consensus Report stated that crestal bone remodeling can be observed in all types of connections,[36] other meta-analyses show, both in vitro and in vivo studies, that internally connected implant–abutment conical connections show the best behavior in terms of peri-implant bone stability.[37] In fact, a recent study, comparing internally connected conical connections versus internal hexagonal connections, found better radiological outcomes in the conical connection group in terms of marginal bone loss, although no clinical and esthetic differences were detected.[38] The same behavior pattern can be observed in similar studies comparing internally connected conical connection versus any other type of connection.[39]

In the present study, the absolute stability of the hard and soft tissues was observed during all the experimental temporal frames. The initial MBL varied from 0.39 (0.63) mm at the prosthesis delivery to 0.40 (0.40) mm at the 1-year follow-up. According to previous reports, less than 0.5 mm of initial peri-implant marginal bone loss could be considered a healthy environment.[40] In the current study, after 1 year, only −0.01 (0.57) mm of MBL change was determined between prosthesis delivery and the 1-year follow-up. In fact, no biologic complications (peri-implant mucositis/peri-implantitis) were detected. Similar observations were also noted in other clinical studies with short-term follow-ups evaluating customized zirconia abutments.[10,21]

Patients were recalled every 3 months for follow-up evaluation and OH instruction reinforcement. The percentage of patients categorized with "no plaque" level increased from 61.9% at baseline to 81% after 1 year. However, BOP was relatively frequent, both at the mesial and distal teeth as well as the implants. It could be speculated that, although the level of OH through the observation period was deemed "Excellent"/"Good," the frequency of BOP could be related to excessive pressure during probing, as has been suggested previously.[41] On the other hand, the frequent recall examinations and the reinforcement of OH instruction protocol used here (every 3 months) could have contributed to this favorable outcome. Clinical studies suggest that a key factor in maintaining peri-implant health is plaque control. This is supported by the fact that zirconia does not seem to improve the quality of peri-implant soft tissues when compared to titanium and titanium nitride abutments.[28,42]

Due to the small number of studies assessing peri-implant soft tissue outcomes and because variables were only registered at the end of the study, a recent systematic review states the need for additional investigations evaluating abutment peri-implant soft tissue outcomes,[43] such as the mucosal margin level, the crown length of the implant restoration, the apico-coronal dimension of the keratinized mucosa, the thickness of the keratinized mucosa, and the level of the interproximal papilla. Accordingly, the current study has also assessed outcomes, such as GZP, the TKG, and the level of the interproximal papilla. These data were recorded at each recall interval, and not only at the end of the study as it occurs in previous investigations.

Comparing titanium to zirconia abutments, investigations have previously evaluated the level of the recession of the mucosal margin with conflicting evidence. Although minimal

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or no differences were detected in two studies,[44,45] Fenner et al.[46] observed a greater amount of gingival recession (0.29 mm) in titanium abutments when compared to zirconia abutments (−0.31 mm). In the current investigation, although the amount of gingival recession was not directly evaluated, gingival recession can be indirectly estimated using GZP. After 1 year, the GZP position changed from 8.24 (1.38) mm at restoration delivery to 7.90 (1.45) mm at the 1-year follow-up, meaning there was a coronal migration of the soft tissue in the range of −0.34 mm. A reduction of gingival recession could be assumed, which is in accordance with Fenner et al.[46] for zirconia abutments. The TKG between titanium and zirconia abutments has also been previously evaluated[10,44] with minimal differences between both abutment types (0–0.4 mm). Outcomes reported here are also in the same line as this measure changed from 2.81 (0.78) mm at restoration delivery to 3.21 (0.93) mm at the 1-year follow-up.

A recent systematic review has emphasized the importance of addressing the peri-implant health of titanium implants with zirconia abutments versus titanium implants with titanium abutments by analyzing the PPD and MBL.[47] The authors found significantly better PPD (0.16 mm lower, $p = 0.03$) and MBL (0.05 mm lower, $p = 0.14$) in single implants with zirconia abutments. The clinical significance of these differences is obviously limited. Our study did not conduct such comparison. In any case, the magnitudes of both PPD (2.53 [0.66] mm) and MBL (0.40 [0.40] mm) can be considered satisfactory.

From the prosthetic point of view, no abutment fractures occurred in the present study. In this sense, a recent systematic review shows significant differences in the fracture rate for zirconia abutments, varying from 1.08% to 17.86%[48] with the majority of them referring to external hexagonal implant–abutment connection, and only a few evaluating zirconia abutments with an internal implant–abutment connection design.[20,21,34,35,49] Ferrari et al.,[28] in a 3-year prospective study using the same CAD–CAM Atlantis abutment design, found significantly higher success rates for titanium and titanium nitride abutments compared to zirconia abutments. A mean zirconia thickness of 375 μm was measured in the internal hexagonal connection area of the Atlantis CAD–CAM zirconia abutments. The authors speculated that a possible explanation for the zirconia abutment failures could be related to the reduced thickness of zirconia at the internal hexagonal connection, milling procedures, and abutment micromotion possibly leading to internal deformation of the implant. The limited number of clinical studies, the variability in zirconia abutment fracture rates, and the fact that data from in vitro studies cannot be extrapolated to fully reproduce actual clinical conditions suggest the need for additional clinical research evaluating the clinical outcomes of zirconia reconstructions with internal implant–abutment design connection. The current investigation aimed at providing data in this sense.

Long-term clinical studies show significant differences in success and survival rates for zirconia abutments. Although Nilsson et al.[20] reported an 87.5% abutment survival rate, Lops et al.[50] reported a 100% survival rate for zirconia abutments after 5 years. In the present research, despite the shorter observation time, zirconia abutment survival rate after 1 year was 100%. These data are in accordance with the survival rates reported by Wittneben et al.[35] also after 1 year of follow-up of similar abutments.

Some factors such as a restorative vertical height (RVH) of 14 mm has been recently suggested to significantly influence zirconia abutment survival rates and was determined as one of the clinical risk limiting factors determining the survival of zirconia abutments in anterior teeth.[34] In the present investigation, each implant reconstruction was planned and manufactured following a prosthetically driven concept, where a full-contour, screw-retained, diagnostic wax-up was fabricated prior to zirconia reconstruction design and fabrication, which in turn helps determine the available RVH. In fact, results from investigations indicate that anatomically designed frameworks are recommended to adequately support the veneering ceramic and minimize the risks of TCs such as porcelain fracture and chipping.[51] After 1 year, our study restorations have not suffered from chipping in any case.

When compared to cement-retained restorations, systematic reviews indicate that screw-retained reconstructions tend to induce few biological complications and more TCs, such as screw loosening.[52] Only one abutment screw loosening was observed in this study, for a total complication rate of 4.7%. This rate is in accordance with other studies that also showed an estimated 5-year screw loosening complication rate of 5.1%. However, this has not been confirmed in other clinical investigations with more than 5-years of clinical follow-up, where screw loosening complication rate was significantly lower.[27,49]

The use of new original prosthetic components in every patient in the current case series must be emphasized. The use of non-original components during the fabrication of implant-supported zirconia reconstructions has been suggested to increase the complication rates significantly. Although some studies supported those discrepancies in the implant–abutment interphase between non-original and original components could be clinically acceptable,[53] other studies confirm the recommendation of using original prosthetic components.[54]

One of the limitations of this investigation is the fact that only one type of ceramic abutment (Atlantis zirconia abutment) was used. Therefore, extrapolation of clinical outcomes to other abutment designs and reconstructions must be cautious. The biomechanical behavior between designs and materials may be significantly different. Another shortcoming of the study is related to the observation period (1 year) as it can be considered a short-term evaluation. However, this observation period is similar to the majority of investigations evaluating zirconia abutments, with follow-ups below 5 years. In any case, to determine the zirconia abutments as predictable and with the same levels of clinical performance as the "gold standard" titanium abutment, additional and longer follow-up randomized clinical investigations must be

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conducted. Moreover, research must take advantage of the recent progress in CAD–CAM technology because it will aid in the standardization of abutment manufacturing protocols reducing risks of internal defects and improving zirconia abutment clinical outcomes.

CONCLUSIONS

Clinical outcomes of single-tooth implant restorations using internally connected, screw-retained, computer-aided design and computer-aided manufacturing monolithic zirconia abutments can be considered a reliable treatment alternative after 1-year clinical observation. However, due to the fact that the present clinical investigation is a short-term prospective case series study, additional randomized controlled clinical trials with longer observation periods are needed to validate the results of the present investigation.

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CONFLICT OF INTEREST STATEMENT

Pablo Galindo-Moreno is a frequent speaker for Dentsply Sirona Implants. Regardless, the authors declare no conflict of interest, either directly or indirectly, in any of the products listed in the manuscript.

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