

CLINICAL STUDY

Dental Implants With a Platform-Switched Morse Taper Connection and an Osteo Growth Induction Surface

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Aim: The aim of this study was to analyze the clinical outcomes after using an innovative implant system characterized by a modern platform-switched Morse taper connection and an osteo growth induction titanium surface (a particular type of SLA surface). Peri-implant bone loss (PBL) and implant success rate were examined after a 1- to 3-year follow-up.

Methods: The study was conducted as a cross-sectional analysis on all patients treated from January 2011 to December 2014 using CLC CONIC implants. Implants were divided into 3 main groups, based on the duration of the follow-up (1 year, 2 years, and 3 years), then subgrouped by diameter, length, and type of prosthetic rehabilitation to compare differences in PBL. X-rays were taken at the time of surgery, at prosthetic loading, at 1 year, and then annually thereafter. Previously-established success criteria were used to assess the implants. Frequency analyses and comparisons between the means (with 95% CI) were conducted for the statistical analysis of the data collected.

Results: One hundred twenty patients met inclusion and exclusion criteria, and completed the follow-up, and were thus eligible for the study, with a total of 261 CLC CONIC implants. The mean follow-up was 22.45 months. No implants failed, giving an overall success rate of 100%. The average PBL at 1-year follow-up was 0.047 mm, at 2 years it was 0.128 mm, and at 3 years it was 0.236 mm.

Conclusions: The CLC CONIC implant system had a high success rate after 1 to 3 years of follow-up, in line with previous reports in the scientific literature. Combining platform switching with the Morse taper connection enabled stable bone levels to be achieved in the short to medium term.

Key Words: Dental implant, Morse taper, OGI surface, platform switching, success rate

(*J Craniofac Surg* 2018;00: 00–00)

In the early 1960s, Brånemark and his team started to develop a new type of dental implant for clinical applications based on a direct connection to the bone, which is known today as osseointegration. After in vivo testing, a detailed surgical protocol was developed in 1969 that aimed to ensure the implant's osseointegration, and the first clinical report was published in 1977.^{1–4} Since then, experiments and developments have continued, leading to microscopic and macroscopic changes to the fixtures, the surface of the implants, and the connection between implant and abutment.

The implant surface is a key factor influencing surgical socket healing and the osseointegration process, and important in the long term for hindering bone resorption and preventing peri-implantitis.^{5–11} The smooth machined surfaces of the first implants were subsequently roughened to extend the bone–implant contact area. Nowadays, this surface roughness is generally obtained by subtractive processes (sandblasting and acid etching), or additive processes (titanium plasma spraying, anodizing, sintering, etc.).^{8–10} SLA surfaces are produced by sandblasting with particles ranging from 250 to 500 μm in size, followed by etching in sulfuric or hydrochloric acid, a combined treatment that considerably increases the surface roughness by comparison with a single subtractive process.^{6,12,13}

The implant–abutment connection has evolved from the original external hexagon to the internal hexagon, to the modern Morse taper or cone screw tapered connection.^{14–16} The principle behind the Morse taper is that of a cone inside a cone, and the trunnion (the male portion) and bore (the female portion) are both evenly tapered.¹⁴ By comparison with their external and internal hexagon predecessors, conical implant–abutment connections produce better results in terms of abutment fit, stability, and seal performance.¹⁶

In the 1990s, the implant–abutment connection was further improved thanks to the concept of “platform switching,” which involves reducing the diameter of the abutment vis-à-vis that of the implant platform. The outer edge of the implant–abutment interface is horizontally relocated inwards, away from the outer edge of the implant platform. This results in a smaller vertical change in crestal bone level than was usually the case when restoring conventional implants with abutments of matching diameter.^{17–19}

The aim of the present cross-sectional study was to test an innovative implant system characterized by a modern platform-switched Morse taper connection and a titanium surface with a particular type of SLA treatment called osteo growth induction (OGI), obtained by sandblasting with large grit followed by double acid etching and the related cleaning cycles. During the study, implants were examined in terms of peri-implant bone loss (PBL), and implant success at 1, 2, and 3 years of follow-up. Peri-implant

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Received April 29, 2018.

Accepted for publication May 23, 2018.

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Claudio Soldini declares a conflict of interest with the implant brand used in this clinical study as co-owner of the company CLC Scientific. The remaining authors report no conflicts of interest.

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ISSN: 1049-2275

DOI: 10.1097/SCS.00000000000004795

bone loss was measured under several conditions, comparing implants of different diameter and length, and supporting different types of prosthetic rehabilitation.

METHODS

Study Design

The study was conducted as a cross-sectional analysis on all patients treated from January 2011 to December 2014 at the SBM dental clinic (Vicenza, Italy) using CLC CONIC implants. The analysis was conducted in accordance with the 1975 Helsinki Declaration, as revised in 2013, regarding research on human subjects. The decision to use CLC CONIC implants was made after a careful case selection based on an accurate clinical and radiographic diagnosis, and after obtaining patients' written informed consent. The following criteria were used to select patients in whom CLC CONIC implants could achieve good results.

Inclusion criteria: more than 18 years of age; partial or total edentulism; sufficient compliance to participate in the follow-up program.

Exclusion criteria: very poor oral hygiene; smoking more than 20 cigarettes/d; abuse of alcohol or drugs; acute oral infections; ASA 4 or 5; remote or recent radiation therapy in the oro-maxillo-facial region; recent chemotherapy; and pregnancy.

Data Collection

A database was created from patients' records for treatments completed between January 2011 and December 2014, and procedures with at least 1 year of follow-up. The sample was divided into 3 groups by duration of follow-up: Group I had a 1-year follow-up; Group II had a 2-year follow-up; and Group III had a 3-year follow-up.

The data recorded included: age, sex, medical and dental history, smoking status (number of cigarettes/day), type of edentulism, reasons for tooth extraction, diameter and length of implant, implant site, number of implants per patient, date of implant placement, any bone regeneration procedures before or during implant surgery, date of functional loading, type of prosthetic rehabilitation, date of latest clinical and X-ray examinations.

Specific surgical sites were grouped by jawbone (maxilla and mandible), and by area (anterior: from canine to canine, posterior: from first premolar). Implants were also grouped by diameter and length, as follows: diameters were Class I (3.5 mm) or Class II (4, 4.5, 5, or 6 mm); and lengths were Class I (6 or 8 mm) or Class II (10, 12, or 14 mm).

Any surgical and prosthetic complications, peri-implant infections and/or suppuration, perceptible implant mobility, implant loss, and crestal bone loss measurements were also recorded to ascertain implant success rates.

Crestal bone level (CBL) was measured for each implant in each patient, considering the lowest point where the crestal bone was in intimate contact with the implant, identified on a calibrated examination of standardized periapical radiographs. Measurements were obtained mesially and distally to each implant using digital software (ImageJ 1.48, National Institutes of Health, Bethesda, MD). The CBL was calculated at the following time-points: at implant insertion (CBL-0), at prosthetic loading (CBL-PL), and at follow-up at 1 year (CBL-1y), 2 years (CBL-2y), and 3 years (CBL-3y). The measurement was rounded up or down to the nearest 0.1 mm with the aid of a sevenfold magnifying lens. A peak scale loupe with a magnifying factor of $\times 7$ and a scale with 0.1-mm increments was used. Periapical X-rays were obtained using customized occlusal templates in conjunction with Rinn holder devices and standard long-cone paralleling techniques.

Implants

The fixtures used in this cross-sectional study were CLC CONIC implants (CLC Scientific, Vicenza, Italy) provided by the manufacturer and purchased by the authors. The implants are made of medical-grade 4 titanium and have a 6° Morse taper connection that allows for platform switching from 0.4 mm (for implants 3.5 mm in diameter) to 1.65 mm (for implants 6 mm in diameter). There is only 1 type of connection, so the same prosthetic abutments can be used for all implant diameters.

CLC CONIC implants have an OGI surface (Sa 1.3 μm) obtained by large grit sandblasting with white corundum followed by double acid etching with a mixture of mineral acids and relevant cleaning cycles. The implant shoulder undergoes the same surface treatment as the rest of the implant to promote bone growth in this area. The manufacturer recommends inserting the implants at different depths among the bone crest, depending on the clinical situation: from the crestal bone to 2 mm below the bone crest.

Implant Success

Patients were recalled every 6 months for a clinical examination as part of their routine oral hygiene program. X-rays were taken at the time of surgery, at prosthetic loading, after 1 year, and annually thereafter, based on a well-established protocol generally associated with successful dental implants.

Implant success rate was ascertained using criteria suggested by Buser et al in 1994,²⁰ and modified by Albrektsson and Zarb in 1998:²¹ absence of persistent pain, dysesthesia, or paresthesia in the implant area; absence of peri-implant infection, with or without suppuration; absence of perceptible implant mobility; and absence of persistent peri-implant bone resorption >1.5 mm during the first year of loading, and 0.2 mm/y in subsequent years. All implants fulfilling these criteria were classified as *successful*, while those failing to meet some of these criteria but still functioning were classified as *surviving*.

Clinical complications, such as pain, dysesthesia, or paresthesia, were assessed by interviewing patients. Any presence of peri-implant infection (with or without suppuration) and implant mobility were assessed by clinical observation and pressure. Any radiographic evidence of complications, such as excessive peri-implant bone resorption or radiolucencies, was assessed on periapical X-rays. All radiographic evidence was obtained with the same X-ray unit, and the same standardization method, using different radiographic settings (kV and mA) depending on the area of jaw considered.

Statistical Analysis

Statistical analyses were performed using SPSS 22.0 software (SPSS Inc, Chicago, IL). All data were first analyzed using descriptive statistics, and a frequency analysis was conducted on the PBL in the different years of follow-up, by subgroup (sex, implant length and diameter, and type of prosthetic rehabilitation).

The 95% confidence intervals of the mean bone loss measurements were calculated by patient subgroup to identify any statistically significant differences.

RESULTS

Patients

A sample of 120 patients treated consecutively between 2011 and 2014 was eligible for this cross-sectional study on the basis of inclusion and exclusion criteria: 72 were female and 48 were male. The mean age of the sample as a whole was 56.4 years (range: 18–89), and it was 59.6 years old (range: 32–85) for the women, and 56.4 (range 18–89) for the men. The mean number of implants

per patient was 2.175 (range: 1–8): 60 patients (50.00%) had 1 implant inserted, 26 (21.67%) had 2, 14 patients (11.67%) had 3, 9 (7.5%) had 5, 4 (3.33%) had 6, 4 patients (3.33%) had 4, 2 patients (1.67%) had 7, and 1 (0.83%) had 8 implants.

Implants

Among the 261 implants included in this study, the follow-up was 1 year for 96, 2 years for 123, and 3 years for 42. The mean follow-up for the sample as a whole was 22.45 months (range: 12–45). The implant was placed in the maxilla in 160 cases, and in the mandible in 101; 72 implants were used for the rehabilitation of edentulous areas in the anterior region, and 189 in the posterior region. No early or late implant loss was recorded. Implant diameters ranged from 3.5 to 6 mm, the most often used (45.2%) being 3.5 mm in diameter. Implant lengths ranged from 6 to 14 mm, and the most used (41%) was 8 mm long. Twenty-nine implants were placed in regenerated bone, obtained using the GBR technique in 17 cases (58.6%), a sinus lift in 9 (32%), and the split crest technique in 3 (10.4%). All implant procedures were completed by the same surgeon (CS).

Prostheses

Different kinds of prostheses were used on the implants involved in this study. Single crowns were used on 94 implants, 59 in the maxilla (17 anteriorly and 42 posteriorly), and 35 in the mandible (3 anteriorly and 32 posteriorly). The mean follow-up after prosthetic loading of these crowns was 21.84 months. Partial bridges were used on another 97 implants, 51 in the maxilla (12 anteriorly and 39 posteriorly), and 46 in the mandible (8 anteriorly and 38 posteriorly); and the mean follow-up after prosthetic loading was 20.16 months. Full arches were used on 70 implants, 46 in the maxilla and 24 in the mandible; and the mean follow-up was 23.04 months.

Success Rate

The mean follow-up period for all the implants as a whole was 22.45 months (range: 12–45) after the implant insertion procedure. For the 261 implants fulfilling inclusion criteria, the success rate was 100%, with no cases of early or late implant loss. At the last available follow-up, all implants were stable and functioning.

Peri-Implant Bone Loss

Implants were placed at a mean depth of 1.44 mm below the bone crest. The mean PBL was 0.047 mm at 1 year of follow-up, 0.128 mm after 2 years, and 0.236 mm after 3 year Figs. 1 and 2). When implant diameter was considered, the PBL was more severe in the subgroup with 3.5 mm implants than in the subgroups with larger-diameter implants at every follow-up point, but the difference was not statistically significant ($P > 0.05$) (Table 1, Fig. 3). When implant length was considered, the PBL was less severe in the subgroup with implants not more than 8 mm long than in the subgroup with longer implants at every follow-up point, but here again the difference was not statistically significant ($P > 0.05$). (Table 2, Fig. 4). As for the types of prosthesis, single crowns coincided with less PBL than partial bridges or full arch rehabilitations, and in this case the difference was statistically significant at 2-year follow-up ($P < 0.05$), but not at any other time ($P > 0.05$) (Table 3, Fig. 5).

DISCUSSION

The present cross-sectional study aimed to examine the success rate and PBL associated with CLC CONIC implants at 1, 2, and 3 years of follow-up.



FIGURE 1. Clinical (A) and radiographic (B) initial situation.

The features of this implant system, which combines a platform-switched Morse taper connection with an OGI surface (obtained by means of sandblasting and acid etching processes), make it particularly interesting because there are very few commercially available implant systems with similar characteristics. Hence, our present study aimed to shed more light on the clinical outcomes achievable with this type of implant.^{13,14,22–24}

With the criteria adopted here to define the success or failure of an implant-prosthetic treatment, the success (and consequent survival) rate was 100% (there were no early or late failures). This result is in line with the scientific literature, and even better than in some clinical studies with similar follow-ups.^{25–32}

Peri-implant bone loss was measured around each implant, and classified by implant diameter and length, and type of prosthetic rehabilitation. The statistical analyses run in this study identified no statistically significant differences in mean PBL between these various subgroups. The only exception emerged from the comparison between the different types of prosthesis in the group examined at 2-year follow-up, while the group considered after 3 years again revealed no statistically significant differences.

A further point of interest regarding the mean differences in PBL lies in that most of the implants revealed no radiographically measurable bone loss with respect to the baseline at the various follow-up times considered. This was true of 90.3% of the implants examined after 1 year, 73.6% of those examined after 2 years, and 60.6% of those examined after 3 years.

On the issue of implant length and diameter, Mumcu et al³³ conducted a retrospective clinical trial in 2011 to assess PBL at 6, 12, 24, and 36 months after prosthetic loading. Four different brands of implant had been used: 47 were Astra Tech; 40 were ITI Standard Plus; 10 were Zimmer SwissPlus; and 29 were BioHorizons Bio-Lok. During the observation period, there were no implant failures and no statistically significant relationship emerged between marginal bone loss and implant length or diameter. Our results for PBL confirm those reported by Mumcu et al, and the CLC CONIC implants that we used were associated with even more limited variations in bone levels. Like Mumcu et al, we concluded that different implant lengths and diameters made no statistically significant difference in terms of PBL.

Commercially available implants vary considerably in terms of their macroscopic features (diameter and length, shape of body and

TABLE 1. Peri-Implant Bone Loss in Relation to Implant Diameter at 1-, 2-, and 3-Y Follow-Up

Mean PBL	D = 3.5 mm	D ≥ / = 4 mm
1-y follow-up	0.132 mm	0.009 mm
2-y follow-up	0.205 mm	0.073 mm
3-y follow-up	0.355 mm	0.16 mm

PBL, peri-implant bone loss.

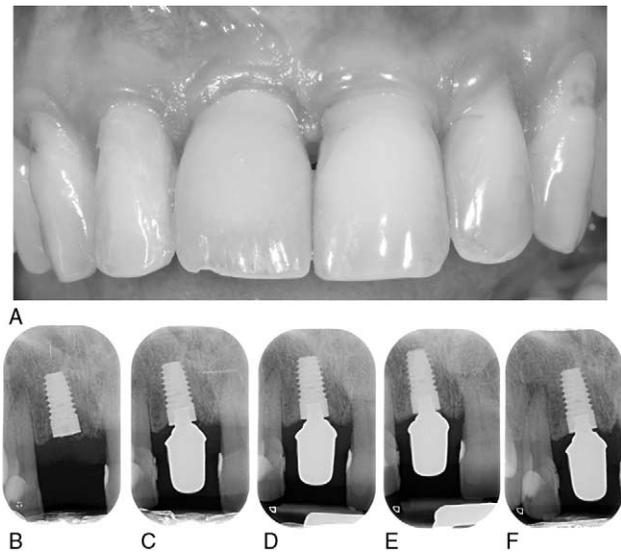


FIGURE 2. (A) Clinical final situation. (B) Rx at implant insertion. (C) Rx at prosthetic loading. (D) Rx after 1 year. (E) Rx after 2 years. (F) Rx after 3 years.

apex, number, size and pitch of threads) and microscopic characteristics (surface finish in particular). It is essential to choose the right implant diameter to avoid the risk of reducing the peri-implant bone with an excessively large implant platform. The appropriate implant diameter is the one that allows for adequate bone trophism, both vestibularly and lingually/palatally, leaving a tooth–implant distance of at least 2 mm. The most widely used, best documented, and scientifically supported implants to achieve excellent long-term results are between 3.75 and 4.1 mm in diameter, while there is less scientific evidence available on narrower implants (3.5 mm or lower in diameter).

In a 2012 retrospective study, Lee et al studied the success and survival rates, and mean variations in bone levels around implants with a diameter of 3.5 mm. They found an annual variation in bone levels of 0.07 mm ± 0.20 mm, in line with the results obtained in our study using 3.5-diameter CLC CONIC implants.³⁴ Our data are also consistent with another study conducted by Veltri in 2008, in which implants 3.5 mm in diameter were considered for the rehabilitation of areas of severely resorbed bone, the endpoints of the study being survival rate and PBL at 1 year of follow-up after prosthetic loading, which were respectively 100% and the 0.30 mm.³⁵

In the scientific community there is currently no unanimously shared opinion on how long an implant defined as short can actually be: some define implants as short if they measure less than 10 mm; others only when they measure between 5 and 7 mm; and yet others set the length of a short implant between 6 and 8.5 mm. There is no published evidence of any statistically significant difference between long implants and short implants in terms of survival and PBL.^{36,37}

TABLE 2. Peri-Implant Bone Loss in Relation to Implant Length at 1-, 2-, and 3-Y Follow-Up

Mean PBL	L < / = 8 mm	L > / = 10 mm
1-y follow-up	0.064 mm	0 mm
2-y follow-up	0.082 mm	0.152 mm
3-y follow-up	0.124 mm	0.34 mm

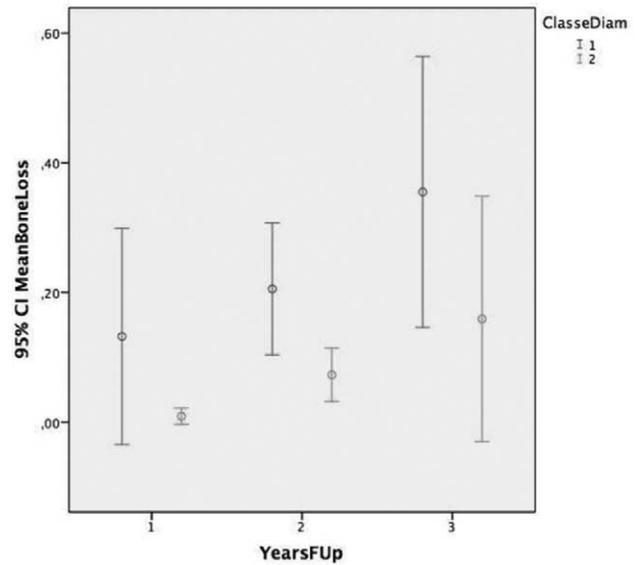


FIGURE 3. Graph 1: peri-implant bone loss was more severe in the subgroup with 3.5 mm implants than in the subgroups with larger-diameter implants at every follow-up point, but the difference was not statistically significant ($P > 0.05$).

In a nonsystematic review of the literature conducted in 2006, Renouard and Nisand found that the short implants used in recent years obtained similar results to those achieved with longer implants. They attributed this to less traumatic surgical techniques for preparing the implant site, and to the macro- and microstructural features of the implant surface, which facilitate early osseointegration.³⁶ In a more recent systematic review of the literature, Annibali et al³⁸ investigated the survival rate, and the biological and mechanical success of implants less than 10 mm long. Their review covered a total of 6793 short implants inserted in 3848 patients, with a mean follow-up of 3.2 years, and a survival rate of 99.1%. The authors concluded that these short implants provided excellent prosthetic support for the follow-up considered. Our present findings are consistent with their conclusions, since the clinical outcomes obtained with short (6 and 8 mm) and long implants (10, 12, 14 mm) were comparable, with no statistically significant differences in terms of PBL.

Our results are also wholly in line with the findings reported by Lemos et al³⁹ in 2016, after reviewing the literature to compare dental implants up to 8 mm with the so-called standard (longer) implants. They considered implant survival rates and PBL in 13 articles concerning 2631 implants, finding no statistically significant differences between the 2 groups, in either implant survival rate or PBL. Here again, the authors concluded that short implants are an excellent resource for the rehabilitation of posterior areas of the maxilla and mandible.

Another feature of implants recently confirmed to guarantee a lower bone resorption is the opportunity for platform switching, which involves using prosthetic components that are under-sized

TABLE 3. Peri-Implant Bone Loss in Relation to the Type of Prosthetic Rehabilitation at 1-, 2-, and 3-Y Follow-Up

Mean PBL	Single Crowns	Partial Bridges	Full Arches
1-y follow-up	0.06 mm	0.04 mm	0 mm
2-y follow-up	0.035 mm	0.11 mm	0.4 mm
3-y follow-up	0.127 mm	0.205 mm	0.46 mm

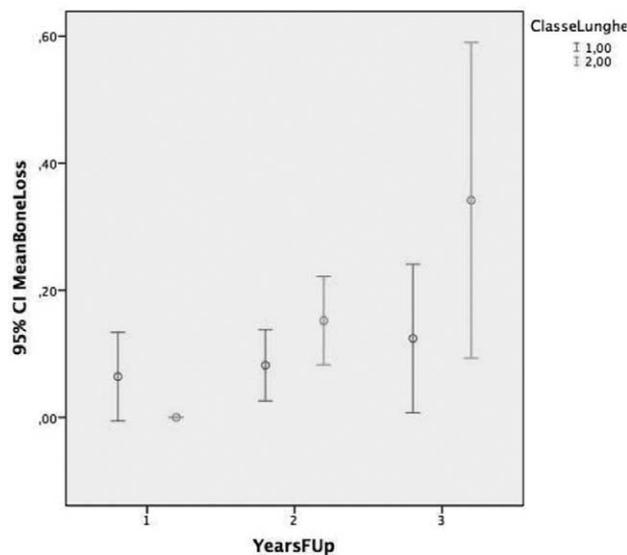


FIGURE 4. Graph 2: peri-implant bone loss was less severe in the subgroup with implants not more than 8 mm long than in the subgroup with longer implants at every follow-up point, but the difference was not statistically significant ($P > 0.05$).

with respect to the implant diameter. Using this approach, the implant–abutment interface is located farther away from the implant shoulder, and closer to the implant axis, so as to increase the distance from the bone of the microgap between implant and abutment, and thus reduce the effect of bone resorption caused by bacterial infiltration.^{40–45}

Many studies have compared bone resorption around implants with and without platform-switched connections. Hurzeler et al⁴⁰ found a 10-fold lower bone resorption and showed a statistically significant difference between the 2 approaches. Rodriguez-Ciurana et al⁴¹ found that platform switching improved peri-implant bone tissue stability by reducing the stress. Vela-Nebot et al⁴² also

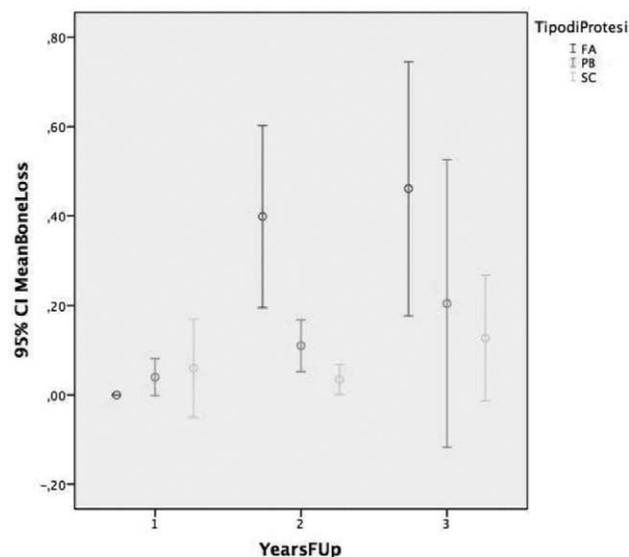


FIGURE 5. Graph 3: single crowns coincided with less peri-implant bone loss than partial bridges or full arch rehabilitations, and the difference was statistically significant at 2-y follow-up ($P < 0.05$), but not at any other time ($P > 0.05$).

reported finding less bone resorption using this solution. In a literature review in 2011, Serrano-Sánchez et al⁴³ investigated the influence of platform switching on PBL, and reported finding much less bone remodeling around platform-switched implant systems than around those with the classic flat-to-flat connection.

A meta-analysis by Chrcanovic on 28 publications also indicated that significantly less bone level reshaping took place around platform-switched implants, but these results should be considered with caution due to the presence of factors that may have confused this result.⁴⁴

The conical connection between fixture and abutment is another characteristic associated with less PBL. In a systematic literature review conducted by Schmitt et al in 2013, it emerged that—compared with other types—the conical connection guaranteed a better fit between fixture and abutment, a better marginal seal, greater stability, and less marginal bone resorption, while the implant survival rate was comparable with that of other types of connection.⁴⁵

A prospective study by Cassetta et al⁴⁶ in 2016 investigated bone resorption around implants with conical connections, the platform switching feature, and an SLA surface. They recorded a bone resorption of 0.26 mm after 1 year, 0.46 mm after 2, and 0.56 mm after 3 years. Comparing our data with those of previous studies clearly shows that CLC CONIC implants, which combine a Morse taper conical connection with a platform switching feature achieved much the same or an even better rate of PBL, supporting the conviction that these 2 characteristics (especially when combined) improve the stability of peri-implant soft and hard tissues.

CONCLUSIONS

In this study, CLC CONIC implants were used in different clinical situations, in different lengths and diameters, and for different prosthetic rehabilitations (from single crowns to full arches). The implant system achieved a high success rate after a 1- to 3-year follow-up, consistently with other reports in the scientific literature. Peri-implant bone loss was very limited in all 3 follow-up groups (at 1, 2, and 3 years), and showed no statistically significant differences in terms of PBL between the different implant lengths and diameters considered. The CLC CONIC implant system seems to offer results in the short and medium terms that are at least as good as other commonly used and documented implant systems, and one of the reasons for its success probably lies in its modern platform-switched Morse taper connection.

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