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Full Length Article

Clinical and radiographic peri-implant changes in patients with a history of COVID-19 infection: A 6-year prospective observational cohort study

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ABSTRACT

Introduction: The COVID-19 pandemic has impacted dental practice. While some studies suggest a link between COVID-19 and early implant failure, others report no adverse effects. This prospective observational cohort study aimed to evaluate long-term peri-implant tissue health and implant survival in patients with and without a history of COVID-19 infection.

Methods: Following the STROBE Statement, 44 implants (16 patients) placed prior to the pandemic were assessed over a maximum six-year period. Patients were divided into two groups based on COVID-19 history: exposure (16 implants) and non-exposure (28 implants). Clinical parameters including implant's probing depth (PD), bleeding index (BI), crestal bone loss (CBL), pain, mobility, and radiographic signs of failure were evaluated at two follow-up visits (2022 and 2024). Statistical analyses were performed with significance set at $p < 0.05$.

Results: All implants remained functional. However, CBL was significantly higher in the exposure group at the second follow-up ($p = 0.044$) and increased significantly in the exposure group over the time ($p = 0.003$). PD and BI increased significantly over time in both groups ($p < 0.05$).

Conclusions: Within the limitations of this cohort, a history of COVID-19 was associated with greater crestal bone loss around dental implants but did not compromise implant survival over six years.

1. Introduction

COVID-19 (Coronavirus Disease 2019) has affected many people worldwide. It is caused by the contagious coronavirus SARS-CoV-2, which can be transmitted through the respiratory system. This virus can lead to a cytokine storm, impacting various body organs and systems such as the respiratory system, cardiovascular and hematopoietic system and even bone regeneration [1].

The restrictions following the COVID-19 pandemic significantly impacted dentistry and implantology treatments [2]. For example, in Spain, during the first nine months after the onset of COVID-19, dental treatments were greatly affected, particularly in urban areas. The workload of inexperienced dentists in the field of implantology increased substantially [3]. Additionally, the pandemic altered antibiotic prescription patterns among dentists in various countries [4] and influenced the types of implant surgeries performed. There was a notable decrease in surgeries involving bone augmentation, sinus lifts, and guided bone regeneration which caused fewer post-operative complications and failures during the pandemic [5].

Some studies have linked the short-term failure of implants to COVID-19 infection, particularly when the infection occurred shortly before or after the implant was inserted into the bone [6–8]. However, other published data have reported no short-term adverse effects on peri-implant tissues due to COVID-19 infection. These studies indicated that smoking and the use of short implants were more strongly associated with a higher risk of early implant failure than COVID-19 [9,10]. Although a review suggested a connection between periodontitis and COVID-19, the same review reported a lack of clinical information

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directly linking COVID-19 infection to peri-implantitis or long-term implant failure [11]. To our knowledge, no prospective cohort study has investigated six-year implant survival in patients who subsequently experienced COVID-19 infection.

Given the conflicting findings in the literature and the limited clinical data on the long-term effects of COVID-19 on dental implant outcomes [6], this prospective observational cohort study was designed to address this gap. The primary objective was to evaluate differences in peri-implant tissue health, including crestal bone loss, probing depth, and bleeding index, between patients with and without a history of COVID-19 infection. The secondary objective was to assess long-term implant survival and clinical signs of implant failure, including mobility, pain, and radiographic peri-implant radiolucency.

The null hypothesis stated that there would be no significant differences in peri-implant tissue parameters or implant survival between patients with and without a history of COVID-19 infection.

2. Material and methods

This prospective observational cohort study was conducted at the UCAM dental setting under ethical committee approval (protocol CE032210) from 2022 to 2024. Following the Declaration of Helsinki principles for medical research involving human subjects, informed consent was obtained from patients, and their thorough medical history was recorded.

Sixteen patients who had received dental implants between one to four years prior to the first follow-up visit were selected from UCAM Dental archives based on strict inclusion and exclusion criteria (Table 1). These patients were recalled for clinical evaluation and medical history review, specifically to determine whether they had tested positive for COVID-19 since the onset of the pandemic.

Patients were categorized into two naturally exposed cohorts: 1. COVID-19 exposed group: patients with a confirmed PCR history of COVID-19 (5 patients, 16 implants), and 2. non-exposed group: patients without a history of COVID-19 (11 patients, 28 implants). This classification was based on retrospective exposure status and did not involve any intervention or randomization.

Follow-up evaluations were conducted in March 2022 and April 2024 to assess implant survival and peri-implant tissue health. All parameters were evaluated by a person who was blind to the COVID-19 history of the patient (A. C.). The clinical parameters assessed included probing depth (PD) measured at six sites around each implant (Mesiolingual (ML), mediolingual (MDL), distolingual (DL), mesiovestibular (MV), mediovestibular (MDV) and distovestibular (DV), bleeding index (BI; recorded as present or absent), and crestal bone loss (CBL). Crestal bone loss was quantified in millimeters using cone-beam computed tomography (CBCT) at each follow-up and compared to baseline radiographs obtained on the day of implant placement. Implant failure was defined as a loss of bone-to-implant contact exceeding 50% of the implant's length [12]. Additional indicators of implant success/failure, including the presence of pain, implant mobility (0 to 3), and radiographic signs of failure such as peri-implant radiolucency, were also evaluated during each follow-up session.

Table 1
Inclusion and exclusion criteria of the study.

Inclusion Criteria	○ Patients aged between 18 and 80 years with at least one conical titanium dental implant placed in the maxilla or mandible following the specified surgical procedure. ○ Patients with no chronic systemic diseases recorded in their medical history. ○ Patients who smoke fewer than 10 cigarettes per day, based on archived information.
Exclusion Criteria	○ Patients with any systemic pathology detected during the first or second visit. ○ Patients who smoke more than 10 cigarettes per day, as identified during the first or second visit.

Data were recorded and analyzed using IBM SPSS Statistics, Version 29.0 (IBM Corp., Armonk, NY) and Microsoft Excel. The Shapiro-Wilk test was used to assess normality. Because the data were not normally distributed and the sample size was small, non-parametric tests were applied. The Mann-Whitney *U* test was used for comparisons between the exposure and non-exposure groups for continuous variables. Within-group changes over time were assessed using the Wilcoxon Signed-Rank Test. Categorical variables were compared between groups using the Chi-square test, while paired binary variables were analyzed using McNemar's test. A p-value < 0.05 was considered statistically significant.

To evaluate the potential effect of clustering arising from multiple implants being contributed by the same participant, a patient-level sensitivity analysis was also performed. For patients with more than one implant, implant-specific measurements were averaged to obtain a single patient-level value for each outcome variable. Between-group comparisons were then repeated using patient-level data, with patients considered the unit of analysis.

The report follows the STROBE Statement guidelines for observational/cohort studies.

3. Results

At the initial evaluation session, a total of 44 implants were assessed after 3 to 6 years, comprising 16 implants in the exposure group and 28 in the non-exposure group. Following a two-year follow-up period, 37 implants (16 from the exposure group and 21 from the non-exposure group) were successfully re-evaluated. These implants corresponded to 12 patients. Four patients (seven implants) were lost to follow-up: three relocated to different cities, and one could not be contacted due to a change in their phone number (Fig. 1).

3.1. Implant-level analysis

Table 2 presents a summary of assessed parameters compared between the exposure group and the non-exposure group across two follow-up periods. Pain was absent in all patients at both times. Radiographic signs of failure (radiolucency) were observed in one implant in the exposure group during the second follow-up. However, this difference was not statistically significant ($p = 0.245$). BI increased significantly within both groups over time ($p = 0.00$), but no significant differences were found between two groups at either time point ($p > 0.05$). No clinically relevant differences in implant mobility were observed between groups or across follow-up visits ($p > 0.05$).

Probing depth measurements showed a statistically significant increase within both groups over time across all six sites ($p < 0.001$). Between-group comparisons revealed significant differences in MDL and DL probing depths at the first follow-up ($p = 0.00$ and $p = 0.041$, respectively), while other sites showed no significant differences. Crestal bone loss (CBL) was significantly higher in the exposure group during the second follow-up ($p = 0.044$), and changes within the exposure group over time were also significant ($p = 0.003$).

Importantly, no implant failures were recorded throughout the study period, indicating a 100% survival rate in both groups.

3.2. Patient-level sensitivity analysis

To assess the potential influence of clustering due to multiple implants being contributed by the same participant, a patient-level sensitivity analysis was performed using mean values per patient. Twelve patients with complete data at both follow-up visits (five with a history of COVID-19 and seven without) were included, and patients were considered the unit of analysis. Between-group comparisons were performed using the Mann-Whitney *U* test. At the first follow-up visit (March 2022), mean probing depth was significantly greater in the COVID-19 group than in the non-COVID-19 group (1.93 mm vs.

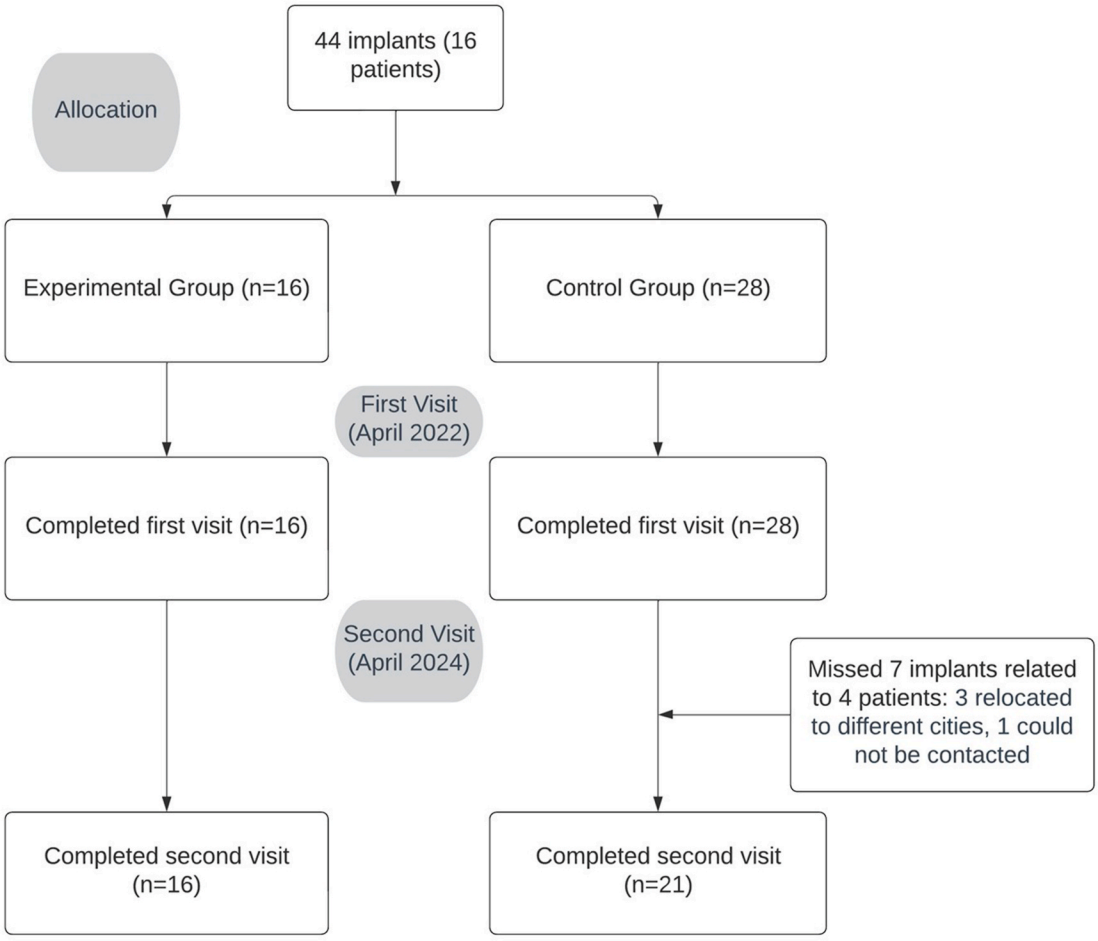


Fig. 1. Flow diagram of the included patients.

Table 2
Clinical and radiographic outcomes at implant level.

Variable		COVID-19 (+) March 2022	COVID-19 (+) April 2024	p-value (within COVID group)	COVID-19 (−) March 2022	COVID-19 (−) April 2024	p-value (within control group)	p-value (between groups, 2022)	p-value (between groups, 2024)
Pain (Yes), n		0	0	*	0	0	*	*	*
Radiolucency (Yes), n		0	1	1.00	0	0	*	*	0.25
Bleeding Index (Yes), n		2	15	**<0.001**	7	17	**<0.001**	0.32	0.26
Mobility (Median ± IQR)		0 ± 0	0 ± 0	0.45	0 ± 0	0 ± 0	1.00	0.28	0.18
CBL (mm)		0.6 ± 0.8	1.0 ± 0.9	**0.003**	0.4 ± 0.6	0.4 ± 0.5	0.15	0.56	**0.04**
Probing depth	MSL	1.9 ± 0.8	4.4 ± 2.0	**0.001**	1.6 ± 0.9	4.4 ± 1.8	**<0.001**	0.12	0.99
	MDL	2.1 ± 1.1	4.1 ± 1.3	**0.001**	1.1 ± 0.4	3.8 ± 1.2	**<0.001**	**<0.001**	0.56
	DL	2.2 ± 1.1	4.4 ± 1.7	**0.001**	1.6 ± 0.8	5.2 ± 1.7	**<0.001**	**0.04**	0.11
	MSV	1.6 ± 0.8	4.3 ± 1.2	**<0.001**	1.5 ± 0.8	4.6 ± 1.7	**<0.001**	0.73	0.65
	MDV	1.4 ± 0.8	3.2 ± 0.7	**0.001**	1.3 ± 0.6	3.1 ± 1.3	**<0.001**	0.83	0.21
	DV	2.1 ± 0.9	4.7 ± 1.3	**0.001**	1.6 ± 0.9	5.2 ± 1.9	**<0.001**	**0.04**	0.53

N implants: COVID-19 (+) = 16 (2022 and 2024); COVID-19 (−) = 28 (2022) and 21 (2024).
CBL: Crestal Bone Loss, Mesiolingual (ML), mediolingual (MDL), distolingual (DL), mesiovestibular (MV), mediovestibular (MDV) and distovestibular (DV).
* Due to the lack of variability (all values were identical), statistical analysis could not be performed for this variable.

1.30 mm; p = 0.042). However, no significant difference was observed at the second follow-up visit (April 2024) (4.69 mm vs. 4.26 mm; p = 0.371). Mean crestal bone loss was also higher in the COVID-19 group at both the first follow-up (0.76 mm vs. 0.17 mm; p = 0.141) and the second follow-up (1.08 mm vs. 0.43 mm; p = 0.072), although these differences did not reach statistical significance. Within-group changes over time were assessed using the Wilcoxon signed-rank test. In the COVID-19 group, increases in probing depth (1.93 mm to 4.69 mm; p = 0.063) and crestal bone loss (0.76 mm to 1.08 mm; p = 0.063) approached but did not reach statistical significance. In the non-COVID-19 group, probing depth increased significantly between follow-up visits (1.30 mm to 4.26 mm; p = 0.016), whereas crestal bone loss showed no significant change (0.17 mm to 0.43 mm; p = 0.273). Overall, the patient-level sensitivity analysis demonstrated a similar trend toward greater peri-implant tissue changes among patients with a history of COVID-19, although statistical significance was attenuated

compared with the implant-level analysis (Table 3).

4. Discussion

This prospective observational cohort study demonstrated that although crestal bone loss was more pronounced around implants in patients with a history of COVID-19 infection, the overall implant survival rate remained comparable between those who had contracted the virus and those who had not. Notably, all implants loaded prior to the COVID-19 outbreak maintained functional stability and showed no signs of failure, resulting in a 100% survival rate across both groups.

Previous studies have shown that COVID-19 infection may increase the risk of bone fractures, hypokalemia, and vitamin D deficiency, along with a more significant reduction in bone mineral density in affected individuals [6,12]. These effects are believed to result from systemic inflammation and immune responses triggered by the virus, which can compromise bone quality and affect the short- and long-term success of dental implants. Specifically, the occupation of ACE-2 (Angiotensin-Converting Enzyme-2) receptors by SARS-CoV-2, the release of pro-inflammatory cytokines such as IL-6, IL-1β, and TNF-α, and microvascular changes that reduce blood supply to bone structures have all been implicated in disrupting normal bone remodeling processes [6,8,12,13].

Osseointegration is a critical determinant of both short- and long-term implant success [14]. Several studies have suggested that COVID-19 may interfere with this process, particularly when infection occurs near the time of implant placement [6–8]. In the present study, although all implants were placed prior to the pandemic, crestal bone levels were lower in patients with a history of COVID-19 infection. This finding suggests a possible association between a history of COVID-19 infection and peri-implant bone remodeling even after osseointegration has been completed. Nevertheless, this bone resorption did not compromise implant survival during six years of follow-up in this investigation, as no failures were observed in either group.

Several previously published studies have reported no short-term adverse effects of acute COVID-19 infection on peri-implant tissues [5,9,10], attributing implant failure more commonly to factors such as smoking or the use of short implants [9]. Vabanaboyina et al. conducted a prospective clinical study and reported significantly lower implant stability, reduced mucosal thickness, and greater marginal bone loss among patients with a previous history of COVID-19 compared with non-infected controls. The authors suggested that systemic alterations associated with COVID-19 may adversely affect peri-implant tissue healing and remodeling [15]. These findings are consistent with the present study, in which greater crestal bone loss was observed among patients with a history of COVID-19. Although this association remained evident in the patient-level sensitivity analysis, statistical significance was not maintained, likely because of the substantially reduced sample size.

Conversely, other research has explored the potential impact of COVID-19 and its associated treatments on bone healing and quality. These include the effects of chronic stress during the pandemic, altered dietary habits, prophylactic medications, and the use of antidepressants [6,8,13]. Yasser Nabil, in a retrospective study, observed a decline in implant success rates following the COVID-19 pandemic, particularly among patients with underlying medical conditions [7]. However, Michael S. Block highlighted the lack of long-term data regarding the impact of COVID-19 on implant success and peri-implant tissue health [6], a concern echoed by Leonardo Mancini and colleagues in their narrative review, which emphasized the absence of evidence linking COVID-19 to long-term implant failure in the oral cavity [11]. The findings of the present study contribute valuable data to this emerging area of research, suggesting that while history of COVID-19 may influence peri-implant bone levels, it does not necessarily compromise long-term implant survival. This study may serve as a foundation for future investigations into the long-term effects of COVID-19 on dental implant outcomes.

While it remains challenging to establish a direct correlation between COVID-19 infection and implant failure, emerging evidence suggests a relationship between COVID-19 and gingival tissue health. Several studies have reported an increased prevalence of gingivitis and periodontitis among COVID-19-positive individuals [10,11,16–18].

In the present study, although some deep probing depths were recorded in both groups, no statistically significant differences were observed in probing depth between COVID-19-positive and COVID-19-negative patients, except two sites: MDL and DV. This suggests that peri-implant tissue health may be more influenced by local factors such as the proximal contact of the prosthesis with adjacent teeth and individual oral hygiene practices, as supported by previous research [19].

This study has several limitations that should be considered when interpreting the findings. The most important limitation is the relatively small sample size, which reduces statistical power and increases the risk of Type II error, particularly for rare outcomes such as implant failure. Consequently, the absence of implant failure in either group should not be interpreted as definitive evidence that COVID-19 has no effect on long-term implant survival. The limited number of participants also restricts the generalizability of the findings to broader implant populations. Recruitment was initiated shortly after the COVID-19 pandemic, during a period when many patients were reluctant to attend non-urgent dental follow-up appointments, and additional losses occurred because of relocation or changes in contact information, which are common challenges in long-term clinical studies. Furthermore, strict eligibility criteria were applied to reduce potential confounding factors, including systemic diseases and heavy smoking, which further reduced the available sample. Although these criteria improved internal validity, they may have limited external validity.

Another limitation relates to the use of implants as the primary unit of analysis. Because some participants contributed more than one implant, observations may not have been completely independent. To address this potential clustering effect, a patient-level sensitivity analysis was performed. Although the direction of the findings remained unchanged, statistical significance was attenuated, likely because of the limited number of patients available for analysis. Therefore, the observed associations should be interpreted cautiously and considered exploratory.

Multiple comparisons were performed for probing depth measurements across six implant sites. Because of the exploratory nature of the study and the limited sample size, no correction for multiple testing was applied. Consequently, some statistically significant findings may represent Type I errors and should be interpreted with caution. In addition, the first clinical assessment was performed in 2022, after the onset of the COVID-19 pandemic. Therefore, differences observed between groups at the first follow-up visit should not be interpreted as evidence of a causal effect of COVID-19 infection because pre-pandemic

Table 3
Patient level Crestal Bone Lost (CBL) and Pocket Depth (PD) comparing between groups and within groups.

Variable	COVID-19 (+) 2022	COVID-19 (+) 2024	p-value (within group)	COVID-19 (−) 2022	COVID-19 (−) 2024	p-value (within group)	p-value between groups (2022)	p-value between groups (2024)
CBL (mm)	0.763	1.076	0.063	0.168	0.431	0.273	0.141	0.072
PD (mm)	1.928	4.694	0.063	1.302	4.258	**0.016**	**0.042**	0.371

patient-level measurements were not available. The longitudinal changes observed between the 2022 and 2024 follow-up visits may provide a more informative assessment of the potential relationship between COVID-19 history and peri-implant tissue health. Accordingly, the present findings should be regarded as preliminary and hypothesis-generating, and larger multicenter longitudinal studies are needed to confirm the observed associations.

Within the limitations of this observational cohort study, it is concluded that the history of COVID-19 was associated with greater crestal bone loss around dental implants, even when the implants had been placed before the onset of the pandemic. However, due to the limited sample size and observational design, a causal relationship cannot be established, and the findings should be interpreted with caution.

Despite the greater crestal bone loss observed in the COVID-19 group, no implant failures were recorded, and implant survival remained 100% in both groups throughout the six-year follow-up period. Larger multicenter longitudinal studies are needed to confirm these findings and further investigate the potential relationship between COVID-19 and peri-implant health.

Author contributions

Conceptualization, A.C. and C.P.-A.M.; methodology, A.C., JE. MSV and C.P.-A.M.; software, F.S., A.C.; validation, F.S., C.P.-A.M., A.L. and J.E.M.S.d.V.; formal analysis, F.S. and A.C.; investigation, A.C. and C.P.-A.M.; resources, A.C., C.P.-A.M. and J.E.M.S.d.V.; data curation, A.C., F. S. and A.L.; writing—original draft preparation, F.S. and A.C.; writing—review and editing, A.C., F.S., C.P.-A.M., A.L. and J.E.M.S.d.V.; visualization, F.S. and A.C.; supervision, J.E.M.S.d.V. and C.P.-A.M. All authors have read and agreed to the published version of the manuscript.

Data availability statement

The original contributions presented in the study are included in the article; further inquiries can be directed at the corresponding author.

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Ethics approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of UCAM (protocol code CE032210, approved on 25th March 2022).

Patients consent statement

Informed consent was obtained from all subjects involved in the study.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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