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Effects of low vitamin D levels on dental implant treatment: a scoping review

Efecto de niveles bajos de vitamina D en el tratamiento de implantes dentales: una revisión de alcance

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ABSTRACT: The aim of this review was to assess low serum levels of vitamin D and its potential effects on dental implant therapy. This study identifies as a scoping review and was conducted using the PRISMA extension for scoping review. Three databases were searched up to September 2024. Low serum levels of vitamin D and dental implants were assessed in animals or humans. Five studies assessed the impact of low vitamin D levels on osseointegration, using radiographs and implant stability analysis at different time points, up to 12 months. Patients with deficient vitamin D levels (<10 ng/ml) experienced greater marginal bone loss compared to those with adequate levels (>30 ng/ml). Two studies supplemented vitamin D in deficient patients, reporting less bone loss and better implant stability. One study correlated vitamin D levels with implant stability quotient, highlighting that an increase in vitamin D significantly improved stability. Analysis in rats revealed that vitamin D deficiency significantly decreased bone-implant contact. Deficient vitamin D levels were associated with early implant loss and osseointegration failure. These results should be interpreted with caution due to the heterogeneity of the studies and the lack of clinical trials.

KEY WORDS: vitamin D, dental implants, low serum levels, scoping review.

INTRODUCTION

Implant therapy is one of the most significant advances in modern dentistry, representing the gold standard for the rehabilitation of lost teeth (Avila *et al*., 2020). However, despite advances in surgical techniques and materials used, implant failures remain a major clinical concern, especially during the critical process of osseointegration, understood as the intimate attachment between the implant surface and the bone, a key process to ensure the stability and longevity of dental implants (Guglielmonti *et al*., 2019).

Osseointegration closely depends on bone metabolism, which is influenced by various factors, including the presence of vitamin D. Vitamin D is known for its role in calcium absorption and activation of osteogenic cells, which in insufficient levels is related to a decreased mineral density, increased susceptibility to fractures and diseases such as osteoporosis (Bikle, 2014). This vitamin participates directly in bone formation, so its deficiency could negatively interfere with implant integration and contribute to complications such as early loss and peri-implantitis. On the other hand, worldwide, vitamin D levels have decreased (Institute of Medicine, 2011), which translates into a significant increase in cases of insufficiency and deficiency. This problem is more prevalent in populations with limited sun exposure or with diets insufficient in vitamin D (Cui *et al*., 2023).

Considering that vitamin D deficiency is an increasingly common global problem, it is paramount to explore how low levels of this vitamin could affect the success of implant therapy. Therefore, this scoping review aims to explore and analyze the existing evidence on the influence of low serum levels of vitamin D on the success of implant therapy, specifically in relation to osseointegration, early implant failure and peri-implantitis. It seeks to provide an overview of the available studies, identify areas of consensus and gaps in research, in order to create a foundation that can guide future research on the impact of vitamin D on implant health.

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MATERIAL AND METHOD

Protocol. This scoping review was conducted using the PRISMA ScR guideline (PRISMA Extension for Scoping Review). The clinical question was formulated using the PCC strategy (P = Population, C = Concept, C = Context), and was formulated as: Do low serum levels of vitamin D influence dental implant therapy in animals and/or humans?

Search strategy and eligibility. The search was conducted in three databases, National Center for Biotechnology Information (NCBI-PubMed), Scopus and Scientific Electronic Library Online (SciELO), between the third and fifth of September 2024. An English Spanish language filter was applied and for the Scopus database a filter of studies linked to dentistry was used. The following keywords were used: “vitamin D” and “dental implant”; the Boolean connector used was “AND”. The following algorithm was obtained: "vitamin D" [All Fields] AND "dental implants" [All Fields]. The search was carried out by two researchers in isolation (MG and MS). Derived from this search among the 3 databases, 48 articles from Pubmed, 28 from Scopus, and 1 result from SciELO were obtained; these were subjected to inclusion and exclusion criteria (Table I), by two independent researchers (MG and MS). In case of discrepancies, these were discussed with a third researcher (EN).

Table I. Inclusion and exclusion criteria.

Eligibility Criteria	Definition
Inclusion	Studies performed on humans or animals receiving dental implants.
	Studies related to the dental field.
	Subjects free from chronic pathologies.
	Low or insufficient serum levels of vitamin D.
	Measurement of clinical outcomes.
	Measurement of *in vitro* results.
	Studies in English or Spanish.
Exclusion	Systematic reviews and meta-analyses.
	Scoping reviews.
	Records that do not report serum levels of vitamin D.
	Subjects with osteoarticular/osteodegenerative diseases.
	Subjects with systemic diseases.
	Microbiological outcomes.
	Genetic outcomes.

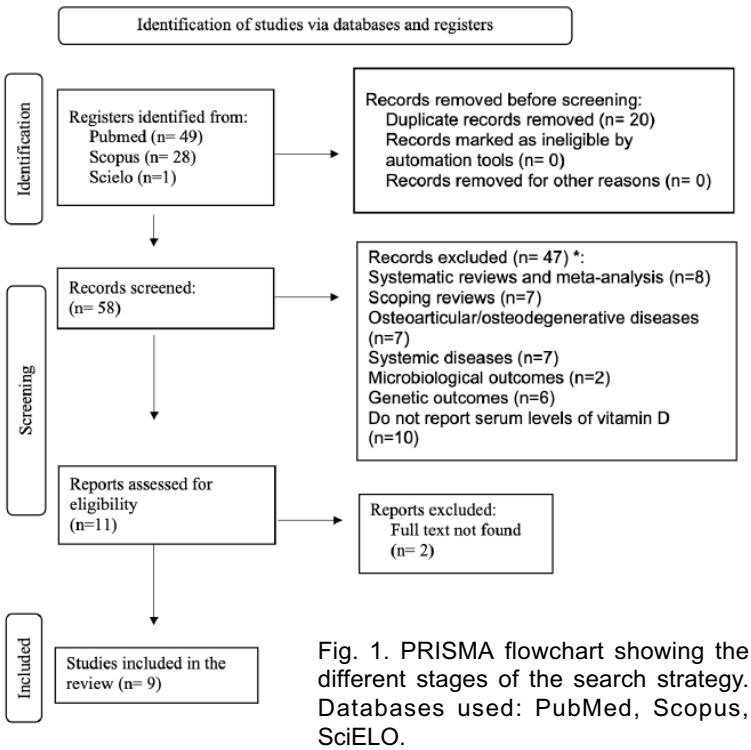

Fig. 1. PRISMA flowchart showing the different stages of the search strategy. Databases used: PubMed, Scopus, SciELO.

Data extraction. The studies were selected using the Rayyan 3.6 program, first using blinding and then discussing the results among the reviewers, who debated using the title and abstract of each article. Duplicates were first eliminated, leaving 58 studies of these 47 were excluded as they did not meet the inclusion criteria.

RESULTS

Literature selection process. The data search yielded a total of 78 studies, of which 49 were found in PubMed, 28 in Scopus and 1 in SciELO. Of these, 20 were eliminated due to being duplicates. After reviewing the abstracts, 47 were excluded for not meeting the inclusion criteria. Of the 11 articles analyzed, 2 were excluded because the complete document was not found. Finally, 9 articles met the inclusion and exclusion criteria, of the type randomized clinical trial, prospective cohort, retrospective cohort and case series, this is summarized in the PRISMA flowchart (Fig. 1).

Characteristics of the sources of evidence. The review included studies performed in humans and animals; three retrospective cohort studies (Mangano *et al*., 2018; Mangano *et al*., 2016; Singh *et al*., 2023), two prospective cohort studies (Bhandage *et al*., 2022; Tabrizi *et al*., 2022), two randomized clinical trials

Table II. Summary of results in humans.

Author	Year	Design (type of study)	Main objective	Study population	Sample size	Study groups	Follow-up	Measured results	Key findings
Singh *et al.*	2023	Retrospective cohort	To correlate serum vitamin D levels with MBL in patients with dental implants using cone beam computed tomography (CBCT)	Adults aged 25 to 45 received delayed loading implants in the posterior mandibular sector. Patients with bone density of 850 to 1250 HU (Hounsfield units)	30 patients	Group with normal vitamin D levels (n=15) Group with deficient vitamin D levels (n=15)	0, 3, and 6 months	Serum vitamin D levels at 6 months follow-up. CBCT measurement of each implant's marginal bone loss (MBL) in the buccal and lingual areas.	A statistically significant difference (p<0.05) for MBL at loading, 3 and 6 months later in both groups. The mean MBL for the normal levels group at loading was 9.08 ± 1.21 and at 6 months follow-up was 8.12 ± 1.25. The mean MBL for the deficient group at loading was 9.69 ± 1.10 and 6 months was 8.80 ± 1.10 which showed a significant difference. The mean difference in MBL in the normal vitamin D group at loading and 3 months was 0.21, and at 6 months was 0.36; for the deficient group, bone loss was 0.36 and 0.89, respectively.
Mangano *et al.*	2018	Retrospective cohort	Relationship between low vitamin D levels and early implant failure.	Adults between 18 and 90 years received Morse connection implants and delayed protocol. Without previous bone regeneration.	885 patients	Patients were grouped according to serum vitamin D levels (<10ng/ml, 10-30ng/ml, >30ng/ml) gender, and age.	4 months	Early implant failure, considering 4 months post-implantation and before connection surgery.	In patients with early implant failure, the mean serum vitamin D level was 25.4 ng/ml (± 12.6; median=24; range=8–55; 95% CI: 21.2–29.5). The incidence of early failure was 4.4% and 11.1% for insufficient and deficient serum levels, respectively. A chi-square test showed no statistically significant difference between groups with reduced serum vitamin D levels (p=0.105).
Mangano *et al.*	2016	Retrospective cohort	Relationship between low vitamin D levels and early implant failure.	Adults undergoing implant therapy with Morse connection and late protocol. Without prior bone regeneration.	822 patients	Grouped according to serum vitamin D levels (<10ng/ml, 10-30ng/ml, >30ng/ml) gender, and age.	4 months	Early implant failure, 4 months post-implantation and prior to connection.	In patients with early implant failure, the mean serum vitamin D level was 25.5 ng/ml (± 13.2; median=24; range=8–55; 95% CI: 20.6–30.4). The incidence of early failure was 2.2% in patients with normal vitamin D levels, 3.9% in those with insufficient levels (10–30 ng/ml), and 9.0% in patients with deficient levels. However, the differences among the three groups were not statistically significant (p=0.15).
Bhandage *et al.*	2022	Prospective cohort	To evaluate the correlation between vitamin D deficiency and implant stability in late end osseous implants.	Adults between 20 and 50 years, partially edentulous, received late internal hexagon connection implants.	20 patients	In one study group, vitamin D levels were measured initially.	0, 3 and 6 months	Serum levels of vitamin D before surgery. Implant stability by ISQ.	For every 1 ng/ml increase in vitamin D, the ISQ increased by 0.48 units at 3 months and 0.62 units at 6 months, with statistical significance observed at 3 months (p=0.01) and 6 months (p=0.002).
Tabrizi *et al.*	2021	Prospective cohort	To evaluate MBL around dental implants in patients with sufficient, insufficient, and deficient serum levels of vitamin D.	Adults who received tissue level implants in the posterior mandibular molar area, and were loaded at 3 months.	90 patients	Group 1: Deficient levels of vitamin D <10 ng/ml Group 2: Insufficient levels of vitamin D 10 to 30 ng/ml. Group 3: Sufficient levels of vitamin D >30 ng/ml.	3 and 12 months	Periapical radiographic evaluation of MBL at loading, 3- and 12-months post loading. Reference implant shoulder. Serum vitamin D levels at loading and 12 months after.	None of the implants failed during follow-up. Correlation between MBL and serum vitamin D level (p < 0.001). Mean MBL was higher in patients with deficient serum vitamin D levels compared with patients with sufficient serum levels. For each one-unit increase in serum vitamin D level, mean MBL decreased by 0.02 mm.

Author	Year	Design (type of study)	Main objective	Study population	Sample size	Study groups	Follow-up	Measured results	Key findings
Garg *et al.*	2020	Randomized Clinical Trial	To evaluate MBL in patients with low vitamin D levels treated with dental implants with or without vitamin D3 supplementation.	Adults between 20 and 40 received immediate implants in the posterior mandibular sector. They present levels <30 ng/ml of vitamin D.	32 patients	Group I: patients with vitamin D <30ng/ml, supplemented with vitamin D. Group II: Patients with vitamin D <30 ng/ml, not supplemented.	0, 3 and 6 months	Serum vitamin D levels at 3 and 6 months in patients in group I. Radiographic evaluation of MBL with periapical, parallelism technique at 7 days, 3, and 6 months post installation in mesial and distal. Reference first implant thread.	A statistically significant difference in MBL values between the groups was observed in the distal region at 3 months ($p < 0.01$–0.05), with higher values in Group I compared to Group II. However, the differences in mesial and distal MBL across various time intervals were not significant within Group I.
Kwiatek *et al.*	2021	Randomized controlled clinical trial	Effect of deficient vitamin D levels and bone level around the implant.	Adults received implants in the posterior mandibular area. Without prior bone regeneration.	122 patients	Group A: <30ng/ml of vitamin D, without supplementation. Group B: <30ng/ml of vitamin D, with vitamin D supplementation (8000 IU) Group C: levels ≥30ng/ml of vitamin D, without supplementation.	6 and 12 weeks	Mesial and distal bone growth of the implant with periapical radiograph using parallelism technique. Bone growth is compared in the different groups and with the different serum vitamin D levels.	A statistically significant correlation ($p < 0.05$) between vitamin D levels and bone level around the implant, 12 weeks after surgery, in supplemented patients. The higher the vitamin D levels on the day of surgery, the greater the bone growth at 6 and 12 weeks.
Fretwurst et al. (13)	2016	Case report	Report of two clinical cases of early implant failure and vitamin D deficiency.	Case 1: Adult, 48 years old, with early implant failure. Previous regeneration. Case 2: Adult, 51 years	2 patients	There are no groups	1, 10 and 14 days	Serum vitamin D levels, both present deficiency (< 20 ng/ml).	After supplementation, successful implantation is achieved at 6 and 4 months respectively.

(Garg *et al*., 2020; Kwiatek *et al*., 2021), one case report (Fretwurst *et al*., 2016) and one experimental in vivo study in an animal model (Kelly *et al*., 2009). A qualitative analysis was carried out which considered the most relevant data, such as author, year of publication, study design, main objective, population, sample size, study groups, follow-up, measured outcomes and main findings (Tables II and III).

Results of individual sources of evidence. Of the results in humans, 2.003 patients were evaluated, only systemically healthy individuals, non-smokers and without active periodontal disease, aged between 20 and 60 years were included. Of the eight studies in humans, five were conducted in a university setting (Fretwurst *et al*., 2016; Mangano *et al*., 2016; Mangano *et al*., 2018; Kwiatek *et al*., 2021; Tabrizi *et al*., 2022) and three did not specify (Garg *et al*., 2020; Bhandage *et al*., 2022; Singh *et al*., 2023).

The study conducted in an animal model evaluated 15 rats, of which 10 were induced to have vitamin D deficiency through deprivation of intake and zero exposure to UV rays (Kelly *et al*., 2009).

Table III. Summary of results in animal model.

Author	Year	Design (type of study)	Main objective	Study population	Sample size	Study groups	Follow-up	Measured results	Key findings
Kelly et al. (14)	2009	In vivo experimental study in animal model (rat)	To evaluate the effect of vitamin D deficiency on implant osseointegration in a rat model.	Male rats with vitamin D deficiency and rats with normal vitamin D levels.	15 rats	Rats with normal levels of vitamin D (n= 5) Rats with vitamin D deficiency (n=10)	14 days	Implant insertion test: double acid etching (DAE) and crystalline deposition of hydroxyapatite nanoparticles (DCD) implants. Non-decalcified histological analysis with scanning electron microscopy	Significantly lower values in the DAE and DCD implant insertion test of the group with vitamin D insufficiency (15.94 ± 8.20 N, n = 7; 15.63 ± 3.96 N, n = 7, respectively) versus the control group (24.99 ± 7.92N, n = 7, p <0.05; 37.48 ± 17.58N, n = 7, p < 0.01, respectively). Significantly lower BIC ratio in the group with vitamin D insufficiency.

Effects of low serum levels of vitamin D on osseointegration. Five studies evaluated the bone level after IOI installation, of these, 3 used long-cone periapical radiographs as a measurement method: Tabrizi *et al*. (2022), with radiographic controls at 3 and 12 months after implant loading; Kwiatek *et al*. (2021), with radiographic control at 1.5 and 3 months; and Garg *et al*. (2020), with radiographic control at 3 and 6 months. Kwiatek *et al*. (2021) also used resonance frequency analysis of electronic technology to measure the implant stability quotient (ISQ) at the time of installation and 3 months later. Bhandage *et al*. (2022), used only ISQ at the time of installation, at 3- and 6-months post-surgery, considering a control periapical radiograph at the time of implant installation; and Singh *et al*. (2023), used CBCT at loading, 3 and 6 months after.

Of the studies that used long cone periapical radiographs as an evaluation instrument, Tabrizi *et al*. (2022), considered the time of loading to measure vitamin D levels and at 12 months post loading, being the only study that assessed implant loading as a variable. Regarding his results, he found a correlation between MBL and serum vitamin D level ($p < 0.001$) and found no correlation between MBL and other variables, such as implant diameter, implant length and patient age; the mean MBL was higher in patients with deficient serum levels (< 10 ng/ml) of vitamin D compared to patients with sufficient serum levels of vitamin D (> 30 ng/ml).

Garg *et al*. (2020) and Kwiatek *et al*. (2021) supplemented one of their study groups with vitamin D levels <30 ng/ml. Garg *et al*. (2020) measured serum vitamin D levels before implant installation, at 3 and 6 months after, however, the measurement was performed exclusively in the supplemented group, the group with deficient levels only recorded measurements at the beginning of the study. Regarding their results, they found a statistically significant difference for the values between the groups ($p < 0.01 - 0.05$) in distal at 3 months, with higher values for group I (supplemented) compared to group II (insufficient levels); the difference in mesial and distal crestal bone levels between various time intervals was not significant in group I and there was less bone loss in patients with insufficient levels of vitamin D who were supplemented. Kwiatek *et al*. (2021), measured vitamin D levels at the time of implant installation, at 1.5 and 3 months, considered 3 study groups, one of them with supplementation, and measured implant stability using ISQ with a mean value of 78.67 ± 6.51 at 3 months in the 3 groups; Their results found that in group C (with levels > 30 ng/ml) the concentration of vitamin D at the time of surgery was significantly ($p < 0.05$) and positively correlated with the bone level at the implant site after 1.5 and 3 months, and there was a statistically significant correlation between vitamin D levels and the bone level around the implant at 3 months after surgery, in supplemented patients and statistical significance was found ($p < 0.05$) for the variations in the bone level at the implant site after 3 months, being significantly higher in group B (supplemented group) than in group A (group with deficient levels).

Bhandage *et al*. (2022), measured vitamin D levels before patients underwent implant therapy and used ISQ as an instrument to measure osseointegration, this at the time of installation, at 3 months and at 6 months. Their results found a positive correlation between ISQ and vitamin D levels at 3 and 6 months; and that for every 1 ng/ml increase in vitamin D levels, the implant stability quotient value increased significantly by 0.48 at 3 months and 0.62 units at 6 months, which was statistically significant at 3 months ($p = 0.01$ and $p = 0.002$, respectively).

Finally, Singh *et al*. (2023) was the only one who used CBCT as a measuring instrument at 3 and 6 months and also considered the time of implant loading for follow-up. Vitamin D levels were measured after implant therapy at 6 months, dividing the study groups into 2, those with normal vitamin D levels (> 30 ng/ml) and those with deficient levels (< 20 ng/ml). His results showed that the mean MBL for the group with normal levels at the time of loading was 9.08 ± 1.21 and at 6 months follow-up it was 8.12 ± 1.25, which shows a gradual bone loss. The mean for the deficient group at the time of loading was 9.69 ± 1.10 and at 6 months follow-up it was 8.80 ± 1.10. A drastic decrease in bone level was observed in the deficient group compared to the normal group. Intragroup comparisons for normal vitamin D levels, the mean difference in bone loss at loading and at 3 months was 0.2, and after 6 months it was 0.36; for the deficient group, bone loss was 0.36 and 0.89, respectively. Greater bone loss was observed in the group with deficient vitamin D levels.

Regarding the experimental in vivo study in rat model, where osseointegration was evaluated, rats that were deprived of vitamin D did not suffer alterations in the levels of 1,25-dihydroxyvitamin D (active form), but in the levels of 25-hydroxyvitamin D (circulating form) in a significant manner ($p<0.01$) (Kelly *et al*., 2009). In this group, the implants showed a significant decrease in implant insertion values, both for those with double acid etching DAE ($n = 7$) and for those modified with crystalline deposition of hydroxyapatite nanoparticles DCD ($n = 7$) whose values were 15.94 ± 8.20 N and 15.63 ± 3.96 N, respectively, when compared with the control group. The transcortical bone-implant contact (BIC) ratio within the transcortical bone region of DAE implants ($n = 4$) and DCD implants ($n = 4$) in the control group was 69.06 ± 11.79 % and 70.31 ± 6.95 %, respectively, and in the vitamin D insufficiency group, the BIC index was significantly decreased to 45.89 ± 13.49 % ($n = 4$; $p < 0.05$) and 38.13 ± 5.25 % ($n = 4$; $p < 0.01$), respectively. Regarding scanning electron microscopy (SEM) analysis, in the vitamin D deficient group, the surface of the DAE and DCD implant tended to show fracture between the implant and the calcified surface, unlike the control group, where a fracture line was observed between the interface of the new bone and the old bone formation, leaving the calcified tissue adhered to the implant surface.

Effects of low serum levels of vitamin D on early failure of dental implants. The criteria evaluated in the studies by Mangano *et al*. (2016; 2018) correspond to early implant failure, which is understood as loss of the implant in the period comprising the first 4 months post-implantation and before the connection surgery. In both cases, early failure was divided into two categories: early failure due to failure in osseointegration and consequent mobility of the IOI, but without infectious symptoms; and early failures with infectious symptoms (inflammation, pain, bleeding, PS>6mm, suppuration and bone resorption > 2.5mm).

Mangano *et al*. (2016) results up to 2016 reported 27 early failures, out of a total of 1625 implants, 19 due to failure in osseointegration and 8 due to peri-implantitis. Other factors such as gender or age were not related to early failure. Although in patients with optimal levels of vitamin D (> 30 ng/ml), a lower incidence of early failures (2.2 %) is reported, compared to patients with deficiency or low levels, no statistically significant difference ($p = 0.15$) was observed between early failure and vitamin D deficiency. It was not reported how many of the failures in osseointegration and peri-implantitis correspond to patients with deficiency or low levels.

Subsequently, Mangano's study continued until 2018 and examined a total of 885 patients and 1740 implants, this because in the previous study a trend of higher incidence of early failure in patients with vitamin D deficiency was observed. However, in this continuation of the study, no statistically significant results were achieved ($p = 0.105$), considering early or late failure of implants with respect to vitamin D levels. 35 early failures were reported (3.9 %), of which 3 (11.1 %) correspond to levels of < 10 ng / ml, 20 for levels of 10 to 30 ng / ml (4.4 %), and 12 for levels of > 30 ng / ml (2.9 %) (Mangano *et al*., 2018).

Regarding the study that included a series of cases (Kwiatek *et al*. 2021), two reports are presented in which there is early implant failure. In the first case, the patient received regenerative therapy in the mandibular region. Two bone level implants were

placed at the third month, which had to be removed on the third day due to intense pain; no signs of inflammation were observed. The patient was admitted at 6 months for the installation of two tissue level implants, which were also removed due to intense pain on the third day. Finally, it was decided to measure serum vitamin D levels, reporting a deficiency of 11 ng/ml. After 6 months of supplementation and healing, a third surgery was successful. In the second case, 2 implants were installed in the posterior mandibular region with guided surgery, without the need for prior regeneration, which had to be explanted on the 15th day post surgery, due to progressive pain that did not subside with analgesics; similar to the previous case, vitamin D levels were measured, which correspond to 20 ng/ml. After supplementing the patient and a period of 4 months, surgery was performed to replace tooth 3.7, achieving an implantation without complications.

Bias Analysis. The characteristics of the evaluated studies are presented in Figure 2 (A, B and C). For the critical analysis of clinical studies, the Cochrane RevMan 5 tool was utilized. Cohort studies and case series were assessed using the JBI criteria (Moola *et al*., 2015). Only one cohort study was determined

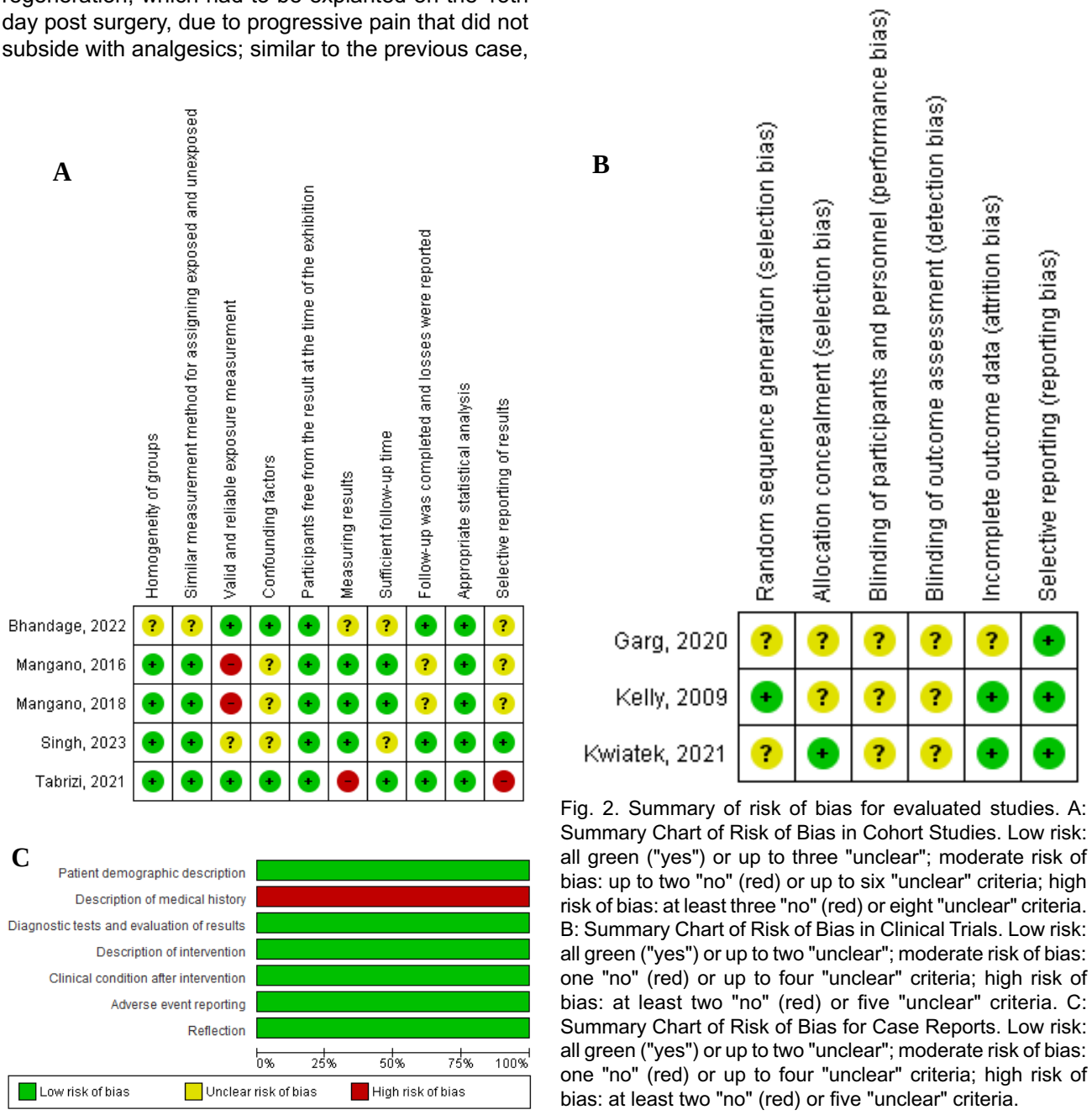

Fig. 2. Summary of risk of bias for evaluated studies. A: Summary Chart of Risk of Bias in Cohort Studies. Low risk: all green ("yes") or up to three "unclear"; moderate risk of bias: up to two "no" (red) or up to six "unclear" criteria; high risk of bias: at least three "no" (red) or eight "unclear" criteria. B: Summary Chart of Risk of Bias in Clinical Trials. Low risk: all green ("yes") or up to two "unclear"; moderate risk of bias: one "no" (red) or up to four "unclear" criteria; high risk of bias: at least two "no" (red) or five "unclear" criteria. C: Summary Chart of Risk of Bias for Case Reports. Low risk: all green ("yes") or up to two "unclear"; moderate risk of bias: one "no" (red) or up to four "unclear" criteria; high risk of bias: at least two "no" (red) or five "unclear" criteria.

to have a low risk of bias (Singh *et al*., 2023), with "unclear" or "no" responses for the items related to follow-up time, which was considered insufficient, and control of confounding factors. The remaining studies were evaluated as having a moderate risk of bias, with cohort studies classified as "unclear" for the items on control of confounding factors, follow-up time, and outcome reporting (Mangano *et al*., 2016; Mangano *et al*., 2018; Bhandage *et al*., 2022; Tabrizi *et al*., 2022).

Among the experimental studies, "unclear" ratings were given for selection, performance, and detection bias (Kelly *et al*., 2009; Garg *et al*., 2020; Kwiatek *et al*., 2021). Finally, the case series was rated as having a low risk of bias, with only one "unclear" rating for the item "description of clinical history." In one of the reported cases, the dosage used for supplementation was not detailed (Fretwurst *et al*., 2016).

DISCUSSION

The objective of this scoping review was to explore and analyze the existing literature regarding the effects of low serum vitamin D levels on dental implant therapy. Three parameters were analyzed, considering osseointegration, early implant loss, and peri-implantitis as primary outcomes. In summary, low serum vitamin D levels appear to negatively influence dental implant therapy by affecting parameters such as osseointegration and early implant loss. Regarding peri-implantitis, no results associated with the search were found. However, low serum vitamin D levels could negatively impact marginal bone loss, with higher mean values observed in patients with deficient serum vitamin D levels (< 10 ng/ml) compared to those with sufficient levels (> 30 ng/ml) (Tabrizi *et al*., 2022; Singh *et al*., 2023).

All studies included in this scoping review assessed serum vitamin D levels, whether at the beginning, during, or at the end of implant therapy, considering the implant in function or not. However, comparisons are challenging due to methodological differences and the variety of measurement instruments used. The most employed tools included periapical radiographs, CBCT, ISQ, and BIC.

Regarding studies evaluating osseointegration, six-month follow-up results using CBCT showed greater marginal bone loss in participants with deficient vitamin D levels, with statistically significant differences between groups (Singh *et al*., 2023). These findings align with a 12-month follow-up study using long cone periapical radiographs, which showed similar results (Tabrizi *et al*., 2022). Both studies assessed serum vitamin D levels at the beginning and at the end of the study. A critical analysis categorized these articles as low risk of bias for Singh *et al*. (2023) and moderate risk for Tabrizi *et al*. (2022). The study by Singh *et al*. (2022) was unclear regarding confounding factors and its six-month follow-up period, which may be insufficient for greater clinical relevance. Meanwhile, the study by Tabrizi *et al*. (2022) faced moderate risk of bias due to using periapical radiographs instead of the gold standard CBCT and selective reporting, as participants moved between study groups. Despite these limitations, these studies are the only ones considering implants in function, allowing the discussion of clinical parameters associated with the osseointegration process. These results align with systematic reviews that determine sufficient vitamin D levels in humans lead to successful osseointegration (Bazal-Bonelli *et al*., 2022; Buzatu *et al*., 2023).

Two other studies used long cone periapical radiographs for measurement and had a maximum follow-up of three (Kwiatek *et al*., 2021) and six months (Garg *et al*., 2020), without considering implants in function. Thus, discussing osseointegration would be premature. Nevertheless, their results suggest greater marginal bone loss in patients with deficient vitamin D levels and significant differences in supplementation among patients with insufficient levels. Both studies were assessed as having a moderate risk of bias, primarily due to unclear random sequence generation and blinding in outcome assessment.

Studies utilizing the ISQ index as a measurement tool reported contradictory results. One study found high implant stability at three months across all groups, regardless of serum vitamin D levels (Kwiatek *et al*., 2021). In contrast, another six-month follow-up study identified a positive correlation between ISQ values and vitamin D levels at three and six months (Bhandage *et al*., 2022). This study concluded that a 1 ng/ml increase in vitamin D levels significantly increased ISQ values at both time points, with statistical significance at three months. These differences might stem from variations in follow-up duration and vitamin D assessment. The first study measured levels only at three months, while the second measured them at three and six months and

used ISQ from the time of implant placement (Bhandage *et al*., 2022). This allowed intra- and intergroup comparisons across time points. Although these findings reached statistical significance in the six-month follow-up study, they should be cautiously interpreted as no control group was used, and participants' vitamin D levels were not reported, resulting in moderate risk of bias (Bhandage *et al*., 2022.

An experimental study on rats demonstrated a significant decrease in implant insertion values compared to the control group. BIC ratios significantly decreased in the deficient group, and SEM analysis revealed a fracture line between the implant and calcified surface in the vitamin D-insufficient group, indicating differences in the osseointegration process of titanium implants (Kelly *et al*., 2009). However, these preclinical findings should not be extrapolated due to a small sample size and a short 14-day follow-up. Primary stability values tend to be minimal at this stage, explained by high osteoclastic activity during the first week's post-implantation, peaking between 14 and 21 days as part of the osseointegration process until the implant becomes functional.

Concerning the effect of serum vitamin D levels on early implant failure, the studies by Mangano *et al*. (2016; 2018) investigating the same cohort over 14 years failed to demonstrate a statistically significant correlation. However, a trend was observed linking early failure to low vitamin D levels. These findings align with systematic reviews and umbrella reviews (Alsulaimani *et al*., 2022; Tallon *et al*., 2024) and can be explained by the low number of early failures detected. An additional failure in this study might have achieved statistical significance. Standardization of these results is challenging due to the lack of bone quality analysis and variations in treated areas, e.g., mandibular anterior versus posterior maxilla, which differ in bone density and availability. Methodological limitations, such as retrospective design allowing only simple statistical analyses, also contribute to moderate risk of bias.

Among other findings, the effects of vitamin D supplementation on implant therapy are noteworthy. In the study by Kwiatek *et al*. (2021), a statistically significant correlation was found between vitamin D levels and bone level around implants at three months post-surgery, with greater bone loss in the vitamin D-deficient group. Similarly, Garg *et al*. (2020) observed differences in distal crestal bone levels at three months, showing higher bone levels in the supplemented group versus those with insufficient vitamin D levels. These results align with other reviews highlighting the benefits of adequate vitamin D levels and supplementation in osseointegration and early implant failure prevention (Nastri *et al*., 2020; Makke, 2022). However, supplementation in patients with sufficient vitamin D levels should be approached cautiously, as high doses may reduce bone density. Administration is considered safe at doses < 4,000 IU/day. Multidisciplinary collaboration among physicians and nutritionists is essential to ensure comprehensive care.

The case series (Fretwurst *et al*., 2016) identified deficient vitamin D levels (< 20 ng/ml) in two patients with early implant failure. Both used bone-level implants, which were removed due to acute pain within three- and 15-days post-surgery. After supplementation, successful reimplantation was achieved. However, the study lacked information on dosage and method of supplementation, limiting its replicability. Although animal models suggest a relationship between vitamin D supplementation and increased BIC (Werny *et al*., 2022), external factors could explain early failure. For instance, one patient underwent bone regeneration surgery, and neither received antibiotics post-implantation. Additionally, the case series design does not allow generalization.

Regarding peri-implantitis, no studies established a relationship with low serum vitamin D levels, likely due to the extended follow-up required for such studies and the challenge of evaluating "low levels" over prolonged periods. Future studies should analyze the effects of normal vitamin D levels or supplementation to investigate their potential relationship with peri-implant diseases and provide long-term follow-up data.

This scoping review identifies that low serum vitamin D levels negatively impact the success of dental implant therapy, mainly by impairing osseointegration, promoting marginal bone loss, and increasing early implant failure. No evidence was found linking vitamin D levels to peri-implantitis. Based on these findings, clinical protocols could include monitoring vitamin D levels before implant surgery and supplementation in deficient cases (< 20 ng/ml). Further research is required to evaluate this association and the long-term impact of supplementation, particularly on peri-implantitis development.

GARRIDO, M.; SÁEZ-PINO, M.; SEGOVIA-CHAMORRO, J. & NICCOLI-MERELLO, E. Efecto de niveles bajos de vitamina D en el tratamiento de implantes dentales: una revisión de alcance. *Int. J. Odontostomat., 19(3)*:252-261, 2025.

RESUMEN: El objetivo de esta revisión fue evaluar los niveles séricos bajos de vitamina D y sus posibles efectos en la terapia con implantes dentales. Este estudio se identifica como una revisión exploratoria y se realizó utilizando la extensión PRISMA para dicha revisión. Se realizaron búsquedas en tres bases de datos hasta septiembre de 2024. Se evaluaron los niveles séricos bajos de vitamina D e implantes dentales en animales o humanos. Cinco estudios evaluaron el impacto de los niveles bajos de vitamina D en la osteointegración, utilizando radiografías y análisis de estabilidad del implante en diferentes puntos temporales, hasta 12 meses. Los pacientes con niveles deficientes de vitamina D (<10 ng/ml) experimentaron una mayor pérdida ósea marginal en comparación con aquellos con niveles adecuados (>30 ng/ml). Dos estudios suplementaron con vitamina D en pacientes deficientes, informando menor pérdida ósea y mejor estabilidad del implante. Un estudio correlacionó los niveles de vitamina D con el cociente de estabilidad del implante, destacando que un aumento de vitamina D mejoró significativamente la estabilidad. El análisis en ratas reveló que la deficiencia de vitamina D disminuyó significativamente el contacto hueso-implante. Los niveles deficientes de vitamina D se asociaron con la pérdida temprana del implante y el fracaso de la osteointegración. Estos resultados deben interpretarse con cautela debido a la heterogeneidad de los estudios y la falta de ensayos clínicos.

PALABRAS CLAVE: vitamina D, implantes dentales, niveles séricos bajos, revisión exploratoria.

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