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REVIEW

Influence of subcrestal implant placement compared with equicrestal position on the peri-implant hard and soft tissues around platform-switched implants: a systematic review and meta-analysis

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Abstract

Aim The aim of this article is to systematically review the effect of subcrestal implant placement compared with equicrestal position on hard and soft tissues around dental implants with platform switch.

Material and methods A manual and electronic search (National Library of Medicine and Cochrane Central Register of Controlled Trials) was performed for animal and human studies published up to December 2016. Primary outcome variable was marginal bone level (MBL) and secondary outcomes were crestal bone level (CBL), soft tissue dimensions (barrier epithelium, connective tissue, and peri-implant mucosa), and changes in the position of soft tissue margin. For primary and secondary outcomes, data reporting mean values and standard deviations of each study were extracted and weighted mean differences (WMDs) and 95% confidence intervals (CIs) were calculated.

Results A total of 14 publications were included (7 human studies and 7 animal investigations). The results from the meta-analyses have shown that subcrestal implants, when compared with implants placed in an equicrestal position, exhibited less MBL changes (human studies: WMD = − 0.18 mm; 95% CI = − 1.31 to 0.95; $P = 0.75$; animal studies: WMD = − 0.45 mm; 95% CI = − 0.66 to − 0.24; $P < 0.001$). Furthermore, the CBL was located at a more coronal position in subcrestal implants with respect to the implant shoulder (WMD = − 1.09 mm; 95% CI = − 1.43 to − 0.75; $P < 0.001$). The dimensions of the peri-implant mucosa seem to be affected by the positioning of the microgap and were greater at implants placed in a subcrestal position than those inserted equicrestally (WMD = 0.60 mm; 95% CI = 0.26 to 0.95; $P < 0.001$). While the length of the barrier epithelium was significantly greater in implants placed in a subcrestal position (WMD = 0.39 mm; 95% CI = 0.19 to 0.58; $P < 0.001$), no statistical significant differences were observed between equicrestal and subcrestal implant positioning for the connective tissue length (WMD = 0.17 mm; 95% CI = − 0.03 to 0.36; $P = 0.10$).

Conclusion This systematic review suggests that PS implants placed in a subcrestal position have less MBL changes when compared with implants placed equicrestally. Furthermore, the location of the microgap seems to have an influence on the dimensions of peri-implant soft tissues.

Clinical relevance

When compared with PS placed in an equicrestal position, subcrestal implant positioning demonstrated less peri-implant bone remodeling.

Keywords Dental implants · Platform switch · Vertical implant position · Insertion depth · Marginal bone level

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Background

Dental implants have become a standardized and predictable treatment modality for the rehabilitation of partially and totally edentulous patients, resulting in high survival and success rates [1–3].

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The stability of hard and soft tissues around dental implants has been recognized to be a key factor for long-term implant success [4]. Traditionally, a vertical marginal bone loss of 1 to 1.5 mm during the first year of function followed by a radiographic marginal bone loss of ≤ 0.2 mm annually has been reported in several studies describing two-piece implants [5, 6]. In recent years, however, preclinical and clinical investigations showed a mean marginal bone loss below what is hitherto accepted as success when specific biological and surgical factors are considered [7].

Several factors can contribute to peri-implant marginal bone loss, such as: establishment of a biologic width [8], vertical soft tissue thickness [9], surgical trauma [10], interimplant distance [11, 12], presence of a microgap at the level of the implant–abutment interface (IAI) [13], implant positioning relative to the alveolar crest [14], macrodesign of the cervical area of the implant (i.e., platform-switching and platform-matching implants) [15], type of implant–abutment connection [4], surface topography of the implant neck [16], micromovements of the abutment (prosthetic components) [17], repeated connection/disconnection of abutments [18], smoking status [19], and peri-implantitis [20].

The results from the studies investigating the influence of microgap on crestal bone resorption [14, 21, 22] have shown that the first bone-to-implant contact (fBIC) is dependent on the location of the interface relative to the surrounding bone level. The most apical location of the microgap was related with greater bone loss [14] and greater inflammatory infiltrate [23]. It should be noted that the implants analyzed in the previous studies had a platform-matched (PM) abutment connection.

In recent years, studies using two-piece implants with an altered horizontal relationship between the fixture diameter and the abutment diameter showed conflicting results about the influence of IAI on marginal bone loss. Jung et al. [24] and Cochran et al. [25] showed that implants placed 1 mm below the bone crest presented the greatest peri-implant bone changes. In contrast, some studies showed minimal bone resorption around platform-switching (PS) implants placed in a subcrestal position [26, 27]. Donovan et al. [28], in a case series study, evaluated the radiographic crestal bone changes around PS implants placed subcrestally (i.e., 1.30–1.40 mm, approximately). The mean marginal bone loss was 0.11 mm after 1-year of follow-up, and most of the observed implants had hard tissue above the implant shoulder. Moreover, the results from histological studies suggested that osseointegration may occur coronal to the IAI [29–31].

Maintenance of crestal bone level (CBL) is crucial for soft tissue preservation [32]. In this context, it has been suggested that PS implants provides more space to establish a proper peri-implant biologic width associated with a reduced apical extension of the junctional epithelium [4, 33–35] and, consequently, less CBL changes [36]. When considering the implant positioning relative to the alveolar crest, some investigations using PS implants showed that the epithelium and peri-implant soft tissue length in implants placed in a subcrestal position were significant larger than that in the equicrestally placed implants [35, 37].

A recent systematic review evaluated the impact of the positioning of the microgap on marginal bone level (MBL) changes [38]. The results showed greater bone level changes when implants were placed equicrestally. In this review, however, PS and PM implants were not analyzed independently. Moreover, no information was reported on other relevant outcomes such as soft tissue dimensions and/or changes in the position of soft tissue margin over time.

Therefore, it seems to be opportune to systematically review the effect of subcrestal implant placement compared with equicrestal position on MBL changes around dental implants with platform switch. It is hypothesized that PS implants placed in a subcrestal position exhibit less MBL changes than equicrestally inserted implants. The specific objectives were (1) to evaluate CBL changes, (2) to assess the soft tissue dimensions (barrier epithelium, connective tissue, and peri-implant mucosa), and (3) to evaluate changes in the position of soft tissue margin.

Material and methods

This systematic review was performed according to the Preferred Reporting Items for Systematic review and Meta-Analyses (PRISMA) statement [39, 40].

Focused question

What is the effect of subcrestal implant placement compared with equicrestal position on the peri-implant hard and soft tissues around dental implants with platform switch?

This question considered the following PICO definitions:

- P: animals/patients with PS implants placed at healed ridges.
- I: PS implants placed subcrestally in relation to crestal bone.
- C: PS implants placed equicrestally in relation to crestal bone.
- O:

  – Primary outcome: histological or radiographic MBL.
  – Secondary outcomes: histological or radiographic CBL, soft tissue dimensions (barrier epithelium, connective tissue, and peri-implant mucosa), and changes in the position of soft tissue margin.

Definition of marginal bone level

In order to homogenize the definition of MBL and to eliminate bias arising from using different definitions, the quantitative analysis was carried out only on those studies that defined the peri-implant marginal bone level as the distance between the implant shoulder to the fBIC.

Search strategy

An electronic search of two databases (MEDLINE via Pubmed and Cochrane Central Register of Controlled Trials) was carried out for articles published up to and including December 2016. No language or year restrictions were applied. The search strategy was conducted using MeSH terms and text words. Detailed search strategies were developed for each database searched.

The following search terms were used in the PubMed database:

((“dental implants” [MeSH Terms] OR (“dental” [All Fields] AND “implants” [All Fields]) OR “dental implants” [All Fields] OR (“dental” [All Fields] AND “implant” [All Fields]) OR “dental implant” [All Fields]) OR (osseointegrated [All Fields] AND implant [All Fields])) AND ((“platform switching”) [All Fields] OR (“platform” [All Fields] AND “switching” [All Fields]) OR (“platform shifting” [All Fields] OR (“platform” [All Fields] AND “shifting” [All Fields]) OR (“platform switch” [All Fields]) OR (“non-matching implant–abutment” [All Fields]) OR (“morse taper dental implant abutment interface” [All Fields]) OR (“morse taper dental implant abutment connection” [All Fields])) AND ((“bone” [All Fields] AND “loss” [All Fields]) OR “bone loss” [All Fields]) OR ((“bone tissue” [All Fields]) AND level [All Fields] AND (“Change” [Journal] OR “change” [All Fields])) OR (“bone remodelling” [All Fields] OR “bone remodeling” [MeSH Terms] OR (“bone” [All Fields] AND “remodeling” [All Fields]) OR “bone remodeling” [All Fields]) OR (“bone resorption” [MeSH Terms] OR (“bone” [All Fields] AND “resorption” [All Fields]) OR “bone resorption” [All Fields]) OR (“crestal bone level” [All Fields]) OR (“crestal bone change” [All Fields]) OR (“crestal bone loss” [All Fields]) OR (“crestal bone remodeling” [All Fields]) OR “(peri-implant bone resorption” [All Fields]) OR (“peri-implant bone remodeling” [All Fields]) OR (“marginal bone” [All Fields])) AND ((“insertion depth” [All Fields] OR (“insertion” [All Fields] AND “depth” [All Fields]) OR “placement depth” [All Fields] OR (“placement” [All Fields] AND “depth” [All Fields]) OR “subcrestal position” [All Fields]) OR (“subcrestal” [All Fields] AND “position” [All Fields]) OR “subcrestal placement” [All Fields]) OR (“subcrestal” [All Fields] AND “placement” [All Fields]) OR “microgap depth” [All Fields]) OR (“microgap” [All Fields] AND “depth” [All Fields]) OR “subcrestal” [All Fields])).

For the Cochrane Central, the key terms used were (Title, Abstract, Keywords): dental implant AND subcrestal.

The following journals were online hand-searched from January 1999 to December 2016: *Clinical Implant Dentistry and Related Research, Journal of Clinical Periodontology*, *Clinical Oral Implants Research*, *European Journal of Oral Implantology*, *Journal of Periodontology*, *Journal of Periodontal Research*, *International Journal of Oral and Maxillofacial Surgery*, *International Journal of Oral & Maxillofacial Implants*, *Journal of Oral and Maxillofacial Surgery*, *International Journal of Periodontics and Restorative Dentistry*, *Implant Dentistry*, and *Journal of Oral Implantology*.

Supplementary searches were undertaken to identify unpublished and ongoing studies on the following electronic resources of clinical trials:

- metaRegister of Controlled Trials (Internet): www.controlled-trials.com
- National Institutes of Health Clinicaltrials.gov (Internet): www.clinicaltrials.gov
- World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP) (Internet): www.who.int/ictrp/en/
- European Union Clinical Trials Register (internet): http://www.clinicaltrialsregister.eu

Finally, references lists of included articles and related review articles were screened to search for additional studies.

Eligibility criteria

The following inclusion criteria were considered:

- Publication in the peer-reviewed literature,
- Animal or clinical studies evaluating PS implants,
- Clinical studies: randomized controlled trials (RCTs), controlled trials, cohort studies/case series, and case-control studies with a minimum of ten implants/subjects per group,
- Follow-up time:

– Human studies: at least 6 months after functional loading (immediate—implant inserted in function within 1 week after its placement [41]—or conventional—implant loaded at least 2 months after the insertion [42]—implant loading)

– Animal studies: at least 2 months after implant placement and non-submerged healing (with or without functional loading)

- Histological (animals) and radiological (animals and humans) assessment of MBL,
- Locally or systemically healthy sites and/or conditions.

The exclusion criteria were as follows:

- Studies with multiple interventions (i.e., ridge augmentations and/or sinus lift),
- Studies with immediate and early implant placement with soft tissue healing [43],
- Studies in the absence of a comparison group.

Screening and selection

Initially, two reviewers (C.V. and X.R.C.) screened independently the titles and abstracts (when available) of all reports identified through the electronic and manual searches. Disagreements between the two reviewers were resolved by discussion. Case reports, letters, and narrative or historical reviews were excluded. Following this, full-text papers were obtained and reviewed independently for studies appearing to meet the inclusion criteria or for which there was insufficient data in the title and abstract to make a clear decision. This step was carried out independently by the same two authors. Again, disagreements regarding inclusion were resolved by discussion. The judgment of a third reviewer (M.C.) was decisive when disagreement persisted. The inter-reviewer reliability was calculated by determining the correlation coefficient with Kappa analysis at every stage of the screening process. The reasons for rejecting studies at this or at subsequent stages were recorded. Furthermore, in cases of overlapping data or duplicate publications the most inclusive data was preferentially selected.

Data synthesis

Two reviewers (C.V. and X.R.C.) independently extracted the data from full-text articles. Any disagreement was resolved by discussion between the two reviewers, including the third reviewer (M.C.). The inter-reviewer reliability of the data extracted was determined using Kappa statistics. If required, the corresponding authors were contacted and requested to provide missing data or additional information. Data were excluded until further clarification was available if agreement could not be reached. In addition, a table was created to organize the data from all the included studies (Tables 1 and 2). The data extracted from human studies were MBL changes and alterations of the position of soft tissue margin, while from animal studies the data extracted were: MBL, CBL, and soft tissue dimensions (barrier epithelium, connective tissue, and peri-implant mucosa).

Quality assessment

The quality assessment of the included studies was performed independently by two authors (C.V. and X.R.C.). The reviewers were blinded to the name of the authors, institutions, and journal titles. A variety of quality assessment methods for different study designs were used.

Human studies

Risk of bias for randomized controlled clinical trials was assessed using the criteria modified from the Cochrane Handbook for Systematic Reviews of Interventions [44]. Briefly, a low risk of bias was estimated when the study provided detailed information about all parameters. A moderate risk was considered if a study failed to provide information on only one of the parameters, while a high risk of bias was estimated if a study showed missing information of two or more parameters [45].

The Newcastle–Ottawa scale was utilized to assess the methodological quality of non-randomized studies [46]. The final scores ranged from 0 to 9, with 0–3 considered of low, 4–6 moderate, and 7–9 high quality, respectively.

Animal studies

For included animal studies, the quality assessment was carried out following the Animal Research: Reporting of In Vivo Experiments (ARRIVE) guidelines [47]. Predefined gradings were applied to the following ARRIVE items [48]: Methods/Ethical statement (5), Methods/Study design (6), Methods/Experimental procedure (7), Methods/Experimental Animals (8), Methods/Housing and keeping (9), Methods/Sample size (10), Methods/Allocation animals to experimental groups (11), Methods/Experimental outcomes (12), and Methods/Statistical methods (13) (Table 3).

Data analysis

For data analysis, the radiographic and/or histological assessment of mean MBL values after respective healing periods was extracted and defined as primary outcome. For primary and secondary outcomes (CBL values, barrier epithelium, connective tissue, and peri-implant mucosa), data reporting mean values and their standard deviations of each study were extracted and weighted mean differences (WMDs) and 95% confidence intervals (CIs) were calculated. Since one study presented MBL changes at mesial and distal sites separately [49], the data were averaged. The authors of this review

Table 1 Main characteristics of selected human studies

Publication	Study design	Follow-up	Methods	Implant type	Number of implants (I) and patients (P)	Region (upper jaw (U) or lower jaw (L))	Survival (%)	Depth (mm)	Mean MBL changes and standard deviation (mm)	Mean soft tissue changes and standard deviation (mm)	Comments
Veis et al. [55]	PS	24 months (T_1)	Radiology (m-d)	Biomet 3i	I, 55; P, ND	U; L	100	0/− 1–2	0, 1.13 (0.42); − 1–2, 0.39 (0.52)		
Koutouzis et al. [50]	RCT	12 months (T_0)	Radiology (m-d)	Ankylos	I, 30; P, 30	U, 14; L, 16	100	0/− 1/− 2	0, − 0.27 (0.45); − 1, 0 (0); − 2, 0 (0)	Buccal: 0, 0.37 (0.91); − 1, 0.30 (0.90); − 2, 0.20 (0.78). Lingual: 0, 0.25 (0.46); − 1, 0.50 (0.52); − 2, 0 (0.47)	MBL was expressed as negative value if the first visible bone-to-implant contact was located apically to the implant shoulder. In situations where bone was seen above the implant shoulder, bone level was recorded as zero.
Romanos et al. [49]	RS	91.83 months	Radiology (m-d)	Ankylos	I, 228; P, 85	U; L	97.80	0/− 0.5 mm or more below the crestal bone level	0, 1.41 (1.65) mesial and 1.34 (1.60) distal; ≥ − 0.5, 1.84 (1.49) mesial and 1.73 (1.31) distal		The mesial and distal shoulders of 228 implants were categorized as follows: subcrestal (n = 197) and crestal (n = 65). The remaining sites (n = 194) were supracrestal and were excluded from the analysis
Kutan et al. [51]	RCT	36 months (T_1)	Radiology (m-d)	Astra Tech	I, 56; P, 28	U, 33; L, 23	100	0/− 1	0, 0.56 (0.35); − 1, 1.21 (1.05)		MBL: Distance between the peak point of the marginal bone and the apex of the implant
Pellicer-Chover et al. [52]	RCT	12 months (T_1)	Radiology (m-d)	Mozo-Grau	I, 23; P, 23	U, 13; L, 10	100	0/subcrestal (mean 2.16 mm)	0, − 0.06 (1.11); subcrestal, 1.22 (1.06)		A positive value indicated that MBL was located coronal to the implant shoulder.
Al Amri et al. [53]	RCT	36 months (T_1)	Radiology (m-d)	Straumann	I, 46; P, 23	L, 46	100	0/− 2	0, − 0.45 (0.2); − 2, 0.30 (0.2)		A positive value indicated that MBL was located coronal to the implant shoulder.
de Siqueira et al. [54]	RCT	8 months (T_0/T_1)	Radiology (m-d)	Neodent	I, 55; P, 11	L, 55	100	0/− 1–3	0, 1.03 (0.60); − 1–3, 0.66 (0.38)	Buccal and lingual: 0, 0.30 (0.46); − 1–3, 0.60 (0.52)	

ND, no data; PS, prospective study; RCT, randomized clinical trial; RS, retrospective study; MBL, marginal bone level; T_0, time point at surgery; T_1, time point at implant loading; m, mesial; d, distal

Table 2 Main characteristics of selected animal studies

Publication	Study design	Follow-up	Methods	Implant type	Number of implants (I) and animals (A)	Region (upper jaw (U) or lower jaw (L))	Survival (%)	Depth (mm)	MBL (IS-fBIC; mm); mean (SD)	CBL (IS-BC; mm); mean (SD)	PMH (mm); mean (SD)	Barrier epithelium (mm); mean (SD)	Connective tissue (mm); mean (SD)
Weng et al. [26]	Randomized study	12 weeks (T_1)	Histology (m-d)	Ankylos	A, 8; I, 16	L	100	0/− 1.5	0, − 1.60 (0.97); − 1.5, − 0.41 (0.72)	0, − 0.69 (0.47); − 1.5, 0.90 (0.46)			
Weng et al. [56]	Randomized study	12 weeks (T_0/T_1)	Histology (m-d)	Ankylos	A, 6; I, 12	L	100	0/− 1.5	0, − 2.08 (1.20); − 1.5, − 1.26 (1.48)	0, − 0.16 (0.83); − 1.5, 1.50 (0.66)			
Barros et al. [57]	Randomized study	8 weeks (T_0/T_2)	Histology (m-d)	Neodent	A, 6; I, 48	L		0/− 1.5	0 (2 mm), 0.92 (0.61); 0 (3 mm), 0.68 (0.57); − 1.5 (2 mm), 0.49 (0.38); − 1.5 (3 mm), 0.37 (0.29)	0 (2 mm), 0.58 (0.63); 0 (3 mm), 0.46 (0.36); − 1.5 (2 mm), − 0.14 (0.77); − 1.5 (3 mm), − 0.47 (0.61)			
Cochran et al. [58]	Randomized study	24 weeks (T_2)	Histology (l-m-d)	Straumann	A, 5; I, 40	L	100	0/− 1	Submerged: 0, 0.303 (0.196); − 1, 0.232 (0.216). Non-submerged: 0, 0.337 (0.336); − 1, 0.135 (0.135)		Submerged: 0, 1.979 (0.531); − 1, 2.331 (0.729). Non-submerged: 0, 1.864 (0.554); − 1, 2.635 (0.789)	Submerged: 0, 1.266 (0.377); − 1, 1.451 (0.436). Non-submerged: 0, 1.132 (0.481); − 1, 1.712 (0.393)	Submerged: 0, 0.706 (0.348); − 1, 0.894 (0.566). Non-submerged: 0, 0.732 (0.354); − 1, 0.923 (0.565)
Huang et al. [37]	Randomized study	16 weeks (T_1)	Histology (l-d)	Bicon/Astra	A, 6; I, 24	L	100	0/− 1.5	0 (Astra), 0.88 (0.54); 0 (Bicon), 1.23 (0.66); − 1.5 (Astra), 0.41 (0.36); − 1.5 (Bicon), 0.41 (0.45)		0 (Astra), 2.03 (0.91); 0 (Bicon), 2.70 (0.82); − 1.5 (Astra), 3.23 (0.85); − 1.5 (Bicon), 3.10 (0.73)	0 (Astra), 1.32 (0.68); 0 (Bicon), 1.51 (0.13); − 1.5 (Astra), 2.12 (0.77); − 1.5 (Bicon), 1.92 (0.45)	0 (Astra), 0.71 (0.41); 0 (Bicon), 1.19 (0.73); − 1.5 (Astra), 1.11 (0.30); − 1.5 (Bicon), 1.18 (0.57)
Schwarz et al. [35]	Randomized study	20 weeks (T_0/T_1)	Histology (b-l)	Camlog	A, 6; I, 24	L	100	0/− 1	Machined abutments: 0, − 0.29 (0.27); − 1, − 0.20 (0.25). Microgrooved abutments: 0, − 0.49 (0.41); − 1, − 0.07 (0.25)	Machined abutments: 0, − 0.35 (0.20); − 1, 0.28 (0.32). Microgrooved abutments: 0, − 0.13 (0.53); − 1, 0.51 (0.26)		Machined abutments: 0, 1.58 (0.31); − 1, 2.39 (1.84). Microgrooved abutments: 0, 1.64 (0.40); − 1, 1.81 (0.56)	Machined abutments: 0, 1.00 (0.28); − 1, 1.29 (0.89). Microgrooved abutments: 0, 1.39 (0.63); − 1, 1.14 (0.09)
Lee et al. [59]	Randomized study	8 weeks (T_0/T_1)	Histology (b-l)	NobelBiocare	A, 5; I, 20	L		0/− 2	Buccal: 0, − 2.07 (0.19); − 2, − 0.88 (0.75). Lingual: 0, − 2.00 (2.52); − 2, − 0.25 (0.53)	Buccal: 0, − 1.45 (0.75); − 2, 0.53 (1.80). Lingual: 0, 0.03 (1.14); − 2, 1.60 (0.66)			

MBL, marginal bone level; IS, implant shoulder; fBIC, first bone-to-implant contact; SD, standard deviation; CBL, crestal bone level; BC, bone crest; PMH, peri-implant mucosa height; T_0, time point at surgery; T_1, time point at second-stage surgery; T_2, time point at implant loading; m, mesial; d, distal; b, buccal; l, lingual

Table 3 Categories to assess the quality of finally selected animal studies (Kilkenny et al. [47]; Schwarz et al. [38, 48])

Item	Description	Grading
5	Methods: ethical statement—nature of the review permission relevant licenses, national and institutional guidelines for the care, and use of animals	0 = clearly insufficient; 1 = possibly insufficient; 2 = clearly sufficient
6	Methods: study design—number of experimental and control groups, any steps taken to minimize bias (i.e., allocation concealment, randomization, blinding)	0 = clearly insufficient; 1 = possibly insufficient; 2 = clearly sufficient
7	Methods: experimental procedure—precise details (i.e., how, when, where, why)	0 = clearly insufficient; 1 = possibly insufficient; 2 = clearly sufficient
8	Methods: experimental animals—species, strain, sex, developmental stage, weight, source of animals	0 = clearly insufficient; 1 = possibly insufficient; 2 = clearly sufficient
9	Methods: housing and husbandry—conditions and welfare-related assessments and interventions	0 = clearly insufficient; 1 = possibly insufficient; 2 = clearly sufficient
10	Methods: sample size—total number of animals used in each experimental group, details of calculation	0 = clearly inadequate; 1 = possibly adequate; 2 = clearly adequate
11	Methods: allocation animals to experimental groups—randomization or matching, order in which animals were treated and assessed	0 = no; 1 = yes
12	Methods: experimental outcomes—definition of primary and secondary outcomes	0 = no; 1 = unclear/not complete; 2 = yes
13	Methods: statistical methods—details and unit of analysis	0 = no; 1 = unclear/not complete; 2 = yes

specifically used only the data concerning the results of PS implants placed in either an equicrestal and subcrestal position from the selected studies. The Cochrane-Q test was performed to assess the degree of heterogeneity among studies and the I^2 index was used to describe the percentage of variation across studies due to heterogeneity (0–40% was interpreted as not be important, and above 40% moderate to considerable heterogeneity may be present) [44]. The study-specific estimates were pooled using both the fixed effect model (inverse variance method) and the random effect model (Dersimonian and Laird method). If a significant heterogeneity was found, the random-effects model was used. On the contrary, the fixed-effects model was applied. Forest Plots were created to graphically represent the difference in outcomes of subcrestal and equicrestal groups for all included studies using implants as the analysis unit. All of the statistical analyses were conducted using RevMan (Review Manager (Computer program) version 5.3, Copenhagen. The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). Statistical significance was defined as a P value < 0.05.

Results

Study selection

Figure 1 illustrates the PRISMA flow diagram representing study selection and inclusion. The electronic and hand search provided 400 citations, including 8 duplicate publications. After exclusion of duplicates, an entire yield of 392 publications was screened by two reviewers considering the formal inclusion and exclusion criteria. Then, after excluding articles based on their titles and abstracts, 36 studies were considered for further investigation (k score = 0.82). For the second phase, a further 22 publications were excluded (k score = 0.89). Detailed reasons for exclusion are stated in Fig. 1. Finally, 14 publications were processed for data extraction.

The search for data from unpublished studies revealed a yield of four registered clinical studies. Only the search in clinicaltrials.gov revealed two studies that met de inclusion criteria, which were announced in status of active but not recruiting (NCT01759537; NCT02867982). Thus, data from unpublished studies were not available for analyses.

Study characteristics

The methodological characteristics of the included studies are shown in Tables 1 and 2.

Study design and follow-up

All evidence was published from 2008 to 2016. Seven of fourteen selected publications were human studies, whereby five were randomized clinical trials [50–54], one was a prospective study [55], and one was a retrospective study [49] (Table 1). The remaining seven publications were animal studies using the canine model [26, 35, 37, 56–59] (Table 2). Follow-up periods ranged between 8 and 92 months after functional loading (conventional [49–53, 55] and immediate [54] loading) for human studies and between 8 and 36 weeks after implant placement for animal investigations.

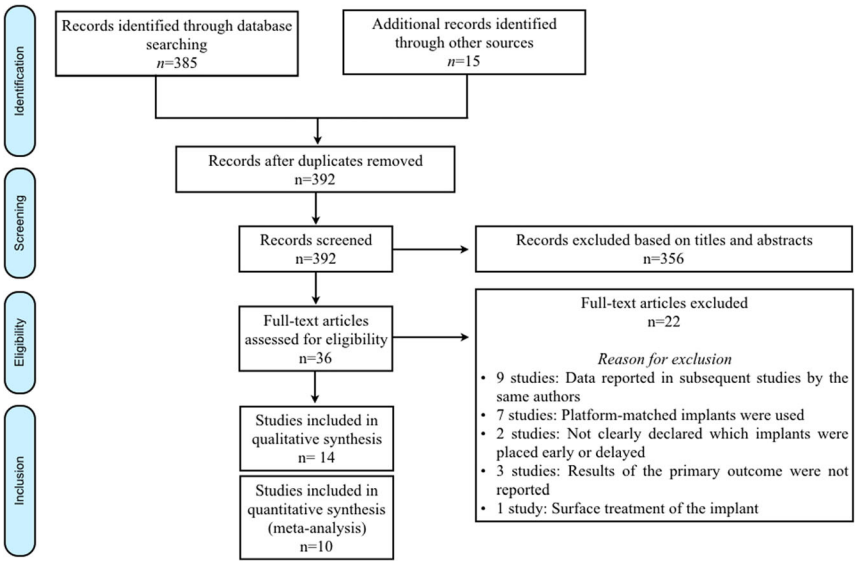

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart of the screening process in the databases

Intervention

Human studies

One study placed the implants 1–2 mm subcrestally [55]; in one study, subcrestal implant placement was considered when mesial and/or distal shoulder was placed at least 0.5 mm below the crestal bone [49]; one study placed the implants 1 mm below bone level [51]; in one study, implants were inserted 2 mm below the alveolar crest [53]; one study placed the implants 1–3 mm subcrestally [54]; one study did not specify such information and only provided data about the mean bone position with respect to the implant platform (i.e., 2.16 mm) [52]; in one study, implants were placed 1 and 2 mm below the buccal aspect of the alveolar crest [50].

None of the studies indicated if the osseous crest was flattened during the surgical phase in order to place the implants at the same bone level. In this context, one trial considered the buccal aspect of the alveolar crest at the time of implant placement [50] and one study indicated that the mesial and distal shoulders of the implants were divided retrospectively into two groups (subcrestal and equicrestal) based on the implant shoulder position on the day of placement surgery [49]. In another study, the mesial and distal cervical platform areas of each implant could be clearly located at the same crestal level classification [55].

After implant insertion, two studies assessed the subcrestal placement depth using a periodontal probe [51] or the implant insertion handle [54]. It should be mentioned at this point that all human studies assessed bone level changes and only two [50, 52] reported baseline measurements for equicrestal and subcrestal groups.

Animal studies

In four studies, subcrestal implants were placed 1.5 mm below the bone crest [26, 37, 56, 57]. In the remaining studies, implants were inserted 1 mm [35, 58] and 2 mm [59] subcrestally. In most of the studies [26, 35, 37, 56, 58], the edentulous osseous ridge was flattened at the time of implant placement.

Evaluation parameters and methods

Human studies

Radiographic data were extracted from human studies. In 3 of these [49, 50, 55], MBL measurements were made from the IAI to the fBIC. Two studies evaluated the peri-implant MBL as the linear vertical distance from the IAI to the most coronal portion of the alveolar bone [52, 53]. In this sense, in another study [54], measurements of the equicrestal implants were performed from the peri-implant bone to the IAI and on subcrestal implants were made from the most apical region of the radiolucent image (i.e., bone crest) to the IAI. In one study, MBL changes were obtained by calculating the distance between the peak point of the marginal bone and the apex of the implant [51]. Apart from the study published by Romanos et al. [49], who included mesial and/or distal shoulder and presented the results separately, measurements were performed on the mesial and distal sides of the implant and the mean of both values was determined.

All studies used standardized periapical X-rays using the parallel technique for assessing the interproximal bone levels, except two that used periapical radiographs or orthopantomographies [49, 55]. The standardization of

radiographic images was ensured by bite registrations [51, 52] or customized film holder [54]. The rest of the studies did not provide information about the radiographic standardization. With the exception of the studies published by Romanos et al. [49] and Veis et al. [55], digital radiographs were used exclusively.

Regarding the position of soft tissue margin, only two studies measured soft tissue changes [50, 54]. In one study, peri-implant mucosa height was recorded at six sites around each implant (mesiobuccal, buccal, distobuccal, distolingual, lingual, and mesiolingual) and it was defined as the distance between the peri-implant mucosa margin and the most coronal part of the permanent restoration [50]. On the other hand, de Siqueira et al. [54] measured pocket probing depth at the midfacial and interproximal surfaces of each implant in order to evaluate the degree of soft tissue recession.

Animal studies

All studies assessed the MBL (primary outcome) using histomorphometric analysis.

In three of seven animal investigations, measurements were performed in the mesio-distal plane combining the mesial and distal aspects [26, 56, 57]. Regarding the bucco-lingual plane, one publication combined the buccal and lingual measurements [35], while in another study buccal and lingual aspects were evaluated separately [59]. In further investigations, measurements of lingual, mesial, and distal aspects [58] and lingual and distal sites [37] were averaged.

In all studies, the MBL was defined as the distance between the IAI and the fBIC [26, 35, 37, 56–59]. Five studies provided information about CBL (i.e., distance from the IAI to the most coronal extent of the crestal bone) [26, 35, 56, 57, 59]. Measurements of soft tissue dimensions were reported in all studies except three [26, 56, 57]. Among these, barrier epithelium was measured from the margin of the peri-implant mucosa to the apical border of the junctional epithelium (aJE), while connective tissue was defined as the distance from aJE to fBIC [35, 37, 58]. Lee et al. [59] defined the epithelial attachment as the distance between the most apical extent of the peri-implant epithelial attachment mucosa and the implant platform along the abutment or the implant. Finally, two studies reported data about the peri-implant mucosa that was defined as the distance from the margin of the peri-implant mucosa to fBIC [37, 58].

Study outcomes

Marginal bone level (main outcome)

Human studies According to the given definition of MBL (i.e., estimated from the IAI to the fBIC), only three studies were considered for the meta-analyses [49, 50, 55]. No statistically significant differences were observed between subcrestal and equicrestal groups (WMD = − 0.18 mm; 95% CI = − 1.31 to 0.95; $P = 0.75$) ($I^2 = 95\%$; $P < 0.001$) (Fig. 2a).

Animal studies All animal studies were considered for the meta-analyses. The WMD between implants placed either at or below the bone crest was − 0.45 mm (95% CI = − 0.66 to − 0.24; $P < 0.001$) ($I^2 = 67\%$; $P < 0.001$) (Fig. 2b), favoring a subcrestal position of the implant shoulder.

Crestal bone level

Animal studies Five animal studies reported outcomes on CBL [26, 35, 56, 57, 59]. A statistically significant difference of − 1.09 mm was found in favor of subcrestal position (95% CI = − 1.43 to − 0.75; $P < 0.001$) ($I^2 = 68\%$; $P = 0.003$) (Fig. 3).

Changes in the position of soft tissue margin

Human studies Regarding soft tissue alterations, Koutouzis et al. [50] observed a coronal migration of the soft tissue margin from placement of the definitive prosthesis to 12-month follow-up visit for all groups, with no significant differences between them (0.37 ± 0.91, 0.30 ± 0.90, and 0.20 ± 0.78 mm for implants placed equicrestally and at 1 and 2 mm below the bone crest, respectively). In this sense, de Siqueira et al. [54] reported that implant placement depths had no effect on soft tissue recession ($P > 0.05$). Due to the different methodology used in the studies, a meta-analysis could not be performed.

Soft tissue dimensions

Animal studies Measurements of histological soft tissue dimensions were reported in all studies except three [26, 56, 57], although the data of one study could not be used since measurements of epithelial attachment were different [59].

The mean length of the peri-implant mucosa calculated in the meta-analysis for implants placed in an equicrestal position was 2.09 mm (95% CI = 1.83 to 2.34) and 2.74 mm (95% CI = 2.44 to 3.03) for subcrestally inserted implants. There were statistical significant differences between equicrestal and subcrestal implant positioning for this outcome for the overall studies (WMD = 0.60 mm; 95% CI = 0.26 to 0.95; $P < 0.001$) ($I^2 = 0\%$; $P = 0.45$) (Fig. 4a).

Implant positioning also affected the length of the barrier epithelium. In particular, a subcrestal position was associated with higher mean values (1.84 mm; 95% CI = 1.59 to 2.09) when compared with an equicrestal position (1.37 mm; 95% CI = 1.23 to 1.51). There were statistical significant differences between equicrestal and subcrestal implant positioning

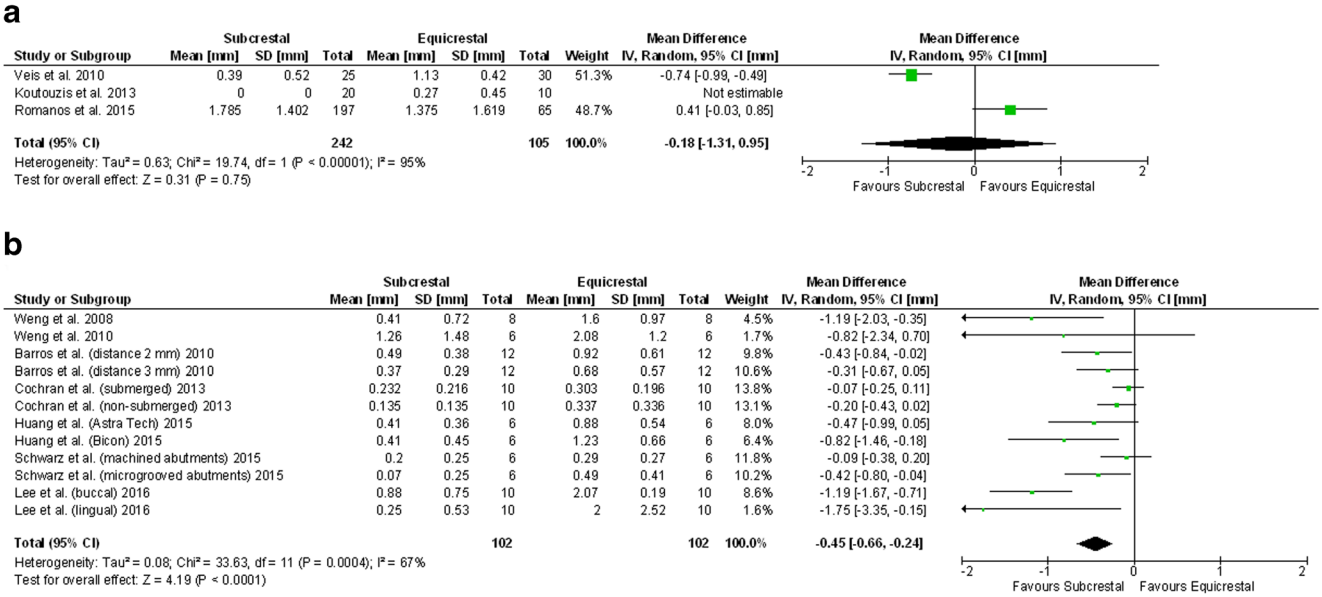

Fig. 2 Forest plots indicating weighted mean difference (95% CI) of marginal bone level between implants placed in either a subcrestal or equicrestal position. **a** Meta-analysis for comparison of marginal bone level among selected human studies. The weighted mean difference was − 0.18 mm (95% CI = − 1.31 to 0.95; $P = 0.75$). The study published by Koutouzis et al. [50] met the selection criteria but did not obtain estimable results and could not be quantified for the meta-analysis. **b** Meta-analysis for comparison of marginal bone level among selected animal studies. The overall weighted mean difference was − 0.45 mm (95% CI = − 0.66 to − 0.24; $P < 0.001$)

for this outcome (WMD = 0.39 mm; 95% CI = 0.19 to 0.58; $P < 0.001$) ($I^2 = 0\%$; $P = 0.54$) (Fig. 4b).

Regarding the length of the connective tissue, this meta-analysis failed to reach statistical significance between equicrestal and subcrestal implant positioning (WMD = 0.17 mm; 95% CI = − 0.03 to 0.36; $P = 0.10$) ($I^2 = 0\%$; $P = 0.52$) (Fig. 4c). The mean length of the connective tissue was 0.91 mm (95% CI = 0.76 to 1.07) and 1.06 mm (95% CI = 0.89 to 1.22) for implants placed in an equicrestal and subcrestal position, respectively.

Quality assessment

The k score between two authors (C.V. and X.R.C.) in quality assessments of RCTs, non-randomized studies, and animal studies was 0.79, 0.89, and 0.83, respectively.

Human studies

Data from the quality assessment are reported in Table 4. From the 5 RCT, only one was considered to have a low risk of bias [50]. The remaining articles were in a high risk of bias.

For the Newcastle–Ottawa Scale, one study [49] scored 6 points and the other one [55] scored 5 points. Thus, the two studies had a moderate quality.

Animal studies

Most of the animal studies were associated with minimum gradings when evaluating checklist items 9 (i.e., housing and husbandry), 10 (i.e., sample size), and 11 (i.e., allocation animals to experimental groups). For items 6 (i.e., study design) and 8 (i.e., experimental animals), the majority of publications were graded with medium scores. Maximum

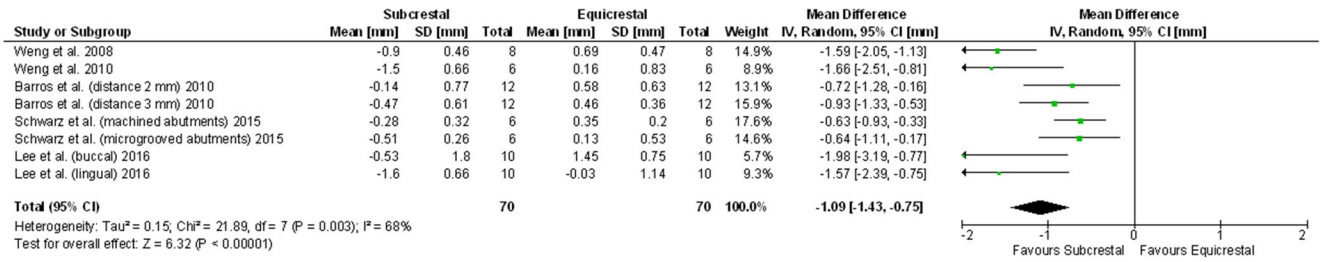

Fig. 3 Forest plot presenting weighted mean difference (95% CI) of crestal bone level among selected animal studies. The weighted mean difference was − 1.09 mm (95% CI = − 1.43 to − 0.75; $P < 0.001$)

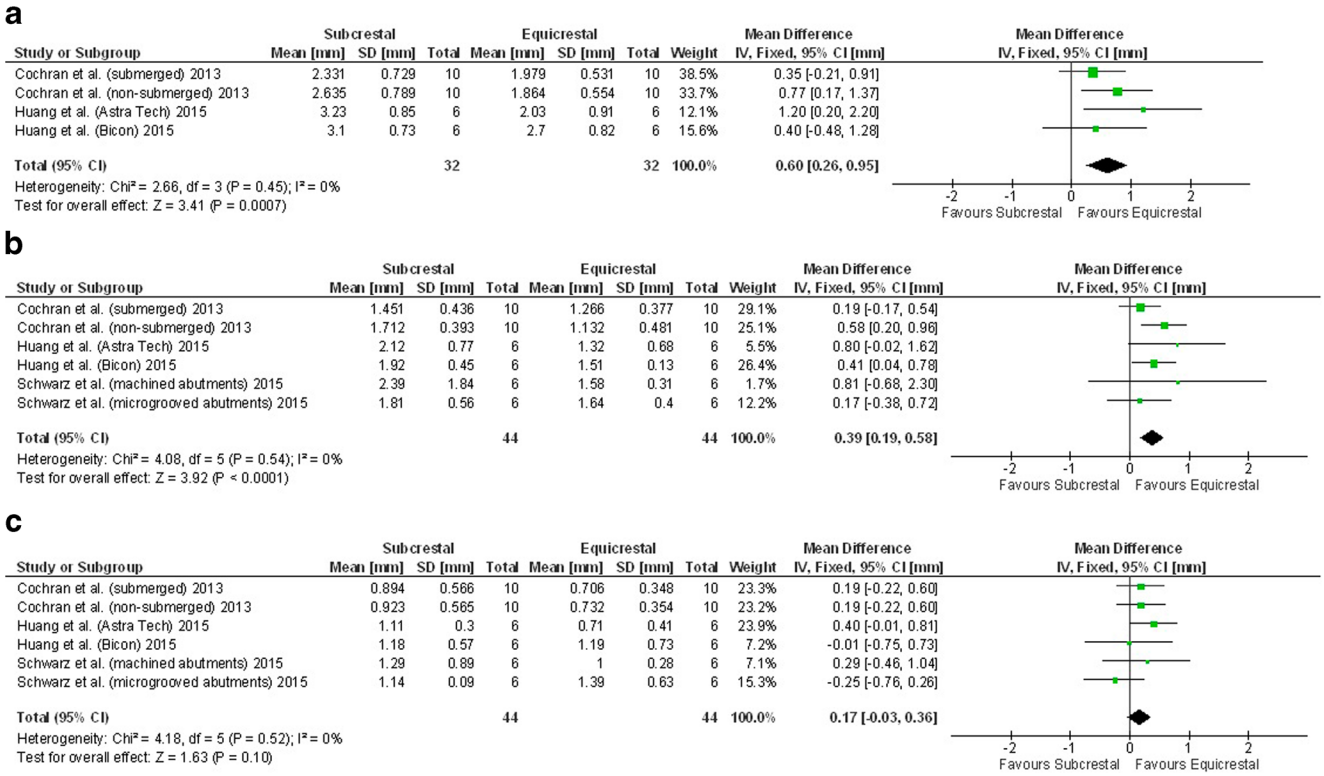

Fig. 4 Forest plot indicating weighted mean difference (95% CI) of peri-implant mucosa height, barrier epithelium, and connective tissue between implants placed in either a subcrestal or equicrestal position. **a** For peri-implant mucosa height, the weighted mean difference was 0.60 mm (95% CI = 0.26 to 0.95; $P < 0.001$). **b** For barrier epithelium, the weighted mean difference was 0.39 mm (95% CI = 0.19 to 0.58; $P < 0.001$). **c** For connective tissue, the weighted mean difference was 0.17 mm (95% CI = − 0.03 to 0.36; $P = 0.10$)

gradings were commonly assigned to checklist item 5 (i.e., ethical statement), 7 (i.e., experimental procedure), 12 (i.e., experimental outcomes), and 13 (i.e., statistical methods). Based on this evaluation, in all seven publications, the estimated risk of bias was considered as high (Table 5).

Discussion

The present systematic review was conducted to address whether there is an impact of subcrestal implant placement on the peri-implant hard and soft tissues around dental implants with platform switch.

Regarding peri-implant bone level, the results from the meta-analyses have shown that subcrestal implants, when compared with implants placed in an equicrestal position, exhibited less MBL changes (human studies: WMD = − 0.18mm; 95% CI = − 1.31 to 0.95; $P = 0.75$; animal studies: WMD = − 0.45mm; 95% CI = − 0.66 to − 0.24; $P < 0.001$); however, significant differences were only observed in animal studies.

These results are in agreement with those published in a similar systematic review that reported greater bone level changes when implants were placed equicrestally (WMD = − 0.48 mm) [38]. It should be mentioned that only one human study [55] was included and the meta-analysis was based on four animal studies [31, 57, 60, 61]. For this reason, Schwarz et al. [38] concluded that subcrestal positioning of two-piece implants should not be advocated in patients. Furthermore, PS and PM implants were not analyzed independently. In this sense, a recent meta-analysis revealed significantly less mean marginal bone change (0.49 mm) at PS implants compared with PM implant–abutment configurations (1.01 mm) [15].

Some studies showed minimal bone loss around PS implants inserted in a subcrestal position [28, 62]. In a human study, Palaska et al. [4] demonstrated no statistically significant differences in bone loss between implants with the same abutment connection pattern but different vertical position after 3 months of healing (screwed internal connection—subcrestal, 0.68 ± 0.07 mm; equicrestal, 0.79 ± 0.06 mm; Morse-tapered internal connection—subcrestal, 0.49 ± 0.06; equicrestal, 0.40 ± 0.07 mm). In contrast with the aforementioned studies, some investigations demonstrated that subcrestal placement of implants had a negative influence on peri-implant tissue remodeling [52, 53].

The discrepancies between the studies might be partially explained by the different methodology used to assess marginal bone loss. In some human studies, bone loss was determined from the IAI to the fBIC [49, 50, 55] and in situations where bone was seen above the implant shoulder, MBL was recorded as zero [50]. On the contrary, other investigations

Table 4 Quality assessment of selected human studies

	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Estimated potential risk of bias
Koutouzis et al. [50]	Low	Low	Low	Low	Low	Low	Low
Kutan et al. [51]	Low	NR	Low	High	Low	Unclear	High
Pellicer-Chover et al. [52]	Low	NR	Low	NR	Low	Unclear	High
Al Amri et al. [53]	Low	NR	Low	High	Low	Unclear	High
de Siqueira et al. [54]	Low	Low	Low	NR	Low	Unclear	High

NR, not reported

Table 5 Quality assessment of selected animal studies

	5 Methods	6 Methods	7 Methods	8 Methods	9 Methods	10 Methods	11 Methods	12 Methods	13 Methods	Estimated potential risk of bias
Weng et al. [26]	1	1	2	1	0	0	0	2	2	High
Weng et al. [56]	1	1	2	1	0	0	0	2	2	High
Barros et al. [57]	2	1	2	1	0	0	1	2	2	High
Cochran et al. [58]	2	1	2	1	0	0	1	1	2	High
Schwarz et al. [35]	1	1	2	1	0	0	0	2	2	High
Huang et al. [37]	2	1	2	1	0	0	0	1	1	High
Lee et al. [59]	1	1	2	2	2	0	0	1	2	High

measured the distance from IAI to the alveolar crest and bone loss was expressed as a positive value if the bone was located coronal to the implant platform (i.e., bone crest), whereas negative values indicated a supracrestal location of the implant (i.e., peri-implant marginal bone) [52–54]. This is of particular importance for the estimation of bone loss and three major parameters are proposed for determining the bone morphology: IAI-fBIC, distance from the IAI to the bone crest, and horizontal bone loss [60].

Although the above-mentioned systematic review [38] has also focused on the effect of the positioning of the microgap on crestal bone level changes, to our knowledge, this is the first systematic review addressing the impact on peri-implant soft tissues. Several preclinical investigations demonstrated that the mucosal attachment included one epithelial and one connective tissue portion of about 1.5–2 and 1–1.5 mm, respectively [8, 63–65]. Recently, the dimensions of the peri-implant mucosa were described in a histological human study [66]. The authors reported that the soft tissue dimension was about 3.6 mm and included a barrier epithelium of 1.9 mm and a connective tissue portion of 1.7 mm. In the present study, meta-analyses were based on animal studies when assessing the soft tissue dimensions. The length of the peri-implant mucosa for implants placed in a subcrestal position was 2.74 mm (95% CI = 2.44 to 3.03) and 2.09 mm (95% CI = 1.83 to 2.34) for equicrestally inserted implants. Regarding barrier epithelium, the meta-analysis resulted in statistically significant higher dimensions of the epithelial length in implants placed in a subcrestal position (WMD = 0.39 mm; 95% CI = 0.19 to 0.58; $P < 0.001$). Conversely, no statistical significant differences were observed between equicrestal and subcrestal implant positioning for the connective tissue length (WMD = 0.17 mm; 95% CI = − 0.03 to 0.36; $P = 0.10$).

As mentioned above, the length of the epithelium was greater for subcrestal implants compared with implants placed equicrestally. The results from this study were corroborated by the clinical observation of greater peri-implant probing depth in subcrestally inserted implants than in implants placed in an equicrestal position [60], since the periodontal probe tended to stop at the histological level of connective tissue in health [67]. In this sense, it must be emphasized that peri-implant probing is essential for establishing a diagnosis of peri-implant diseases and baseline probing measurements for subcrestal implants are crucial for monitoring the peri-implant conditions [68].

Only two human studies provided data regarding the influence of implant placement depth on clinical changes in the position of soft tissue margin [50, 54]. As an apical shift in the position of the soft tissue margin may compromise esthetics, the impact of implant insertion depth on soft tissue changes must be investigated.

Maintenance of CBL is crucial for soft tissue preservation [32], thus facilitating oral hygiene and maintenance of gingival esthetics [54]. The results of the present meta-analyses, based on animal studies, showed that subcrestal implant placement, when compared with equicrestal positioning, was associated with a location of the implant shoulder below the bone crest. In this context, subcrestal position of dental implants has been proposed in esthetic areas to obtain an ideal emergence profile for the prosthetic rehabilitation, and to decrease the risk of exposure of the metal top of the implant or of the abutment margin [32, 69].

The results of the current review should be interpreted with caution. The data were extracted from 14 publications (7 human studies and 7 animal investigations) from which, only 1 was judged to have a low risk of bias. Furthermore, there was a significant heterogeneity between studies and differed regarding the implant–abutment connection type, implant–abutment mismatch size, interimplant distance, number of abutment dis/reconnections, and surface texture at the implant neck.

Due to the high risk of bias in the selected studies, there are some limitations that should be considered. First, few clinical studies with low numbers of patients were available and the data were extracted mainly from animal studies. Second, there was not enough evidence from RCT in the selected literature.

Within the limitations of this systematic review and meta-analysis, the following conclusions can cautiously be drawn: (1) the current evidence based on clinical and preclinical studies suggest that PS implants placed in a subcrestal position seem to have less marginal bone level changes when compared with implants placed equicrestally. However, significant differences were only observed in animal studies; (2) data from animal experiments showed that PS implants placed in a subcrestal position were associated with a location of bone crest coronal to the implant shoulder; (3) results from studies using animal models indicated that the dimensions of the peri-implant mucosa at PS implants seem to be affected by the positioning of the microgap and were greater at implants placed in a subcrestal position than those inserted equicrestally. While the length of the barrier epithelium was significantly greater in implants placed in a subcrestal position, no statistical significant differences were observed between equicrestal and subcrestal implant positioning for the connective tissue length; (4) the impact of the positioning of the microgap on soft tissue margin changes around PS implants lacks documentation and may not allow for any conclusions; and (5) more homogeneous studies with a longer follow-up are needed to confirm this tendency.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent For this type of study, formal consent is not required.

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