The effect of implant-abutment junction position on crestal bone loss. A systematic review and meta-analysis.

Muhammad H. A. Saleh[1], BDS, MS; Andrea Ravidà[1], DDS, MS; Fernando Suárez-López del Amo[2], DDS., MS; Guo-Hao Lin, DDS, MS[3]; Farah Asa'ad, BDS, MS[4] and Hom-Lay Wang[5], DDS, MS, PhD

[1] Post-graduate student, Graduate Periodontics, Department of Periodontics and Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, MI, USA.

[2.] Assistant Professor, Department of Periodontics, University of Oklahoma, College of Dentistry, Oklahoma City, OK, USA.

[3] Clinical Assistant Professor, Department of Orofacial Sciences, University of California, San Francisco, CA, USA.

[4] PhD student, Department of Biomedical, Surgical & Dental Sciences, University of Milan, Milan, Italy.

[5] Professor and Director of Graduate Periodontics, Department of Periodontics and Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, MI, USA.

Corresponding author:

Hom-Lay Wang, DDS, MSD, PhD

Department of Periodontics and Oral Medicine, University of Michigan School of Dentistry

1011 North University Avenue

Ann Arbor, Michigan 48109-1078, USA.

TEL: (734) 763-3325; FAX: (734) 936-0374

E-mail address: homlay@umich.edu

Conflict of interest

The authors declare they have no conflict of interest with this study. The authors do not have any financial interests, either directly or indirectly, in the products or information listed in the paper.

Author contribution

Muhammad H. A. Saleh: Concept, design, data extraction, manuscript preparation.

Andrea Ravidà: Data collection, drafting article.

Fernando Suárez-López del Amo: Manuscript preparation, final revision.

Guo-Hao Lin, DDS, MS: Statistics.

Farah Asa'ad: Data collection.

Hom-Lay Wang: Study supervisor and advisor, final revision

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Abstract

Purpose: To investigate the effect of the apico-coronal implant position on early and late crestal bone loss (CBL), in bone and tissue level implants.

Methods: Electronic and manual literature searches were conducted for controlled clinical trials reporting on CBL before and after functional loading of implants. Random effects meta-analyses were applied to analyze the weighted mean difference (WMD) and meta-regression was conducted to investigate any potential influences of select confounding factors.

Results: Fourteen articles were included in the systematic review and 12 were included in the quantitative synthesis. For bone level implants, WMD comparing *early* CBL in equi and subcrestal placement was 0.15 mm (p=0.18). For analyses of *late* CBL in bone level implants, equi and subcrestal placement revealed a 0.03 mm WMD (p=0.88). Where in supra and subcrestal placement, WMD was 0.04 mm (p=0.86). The comparison presented considerable heterogeneity between these two arms, where the p value for chi-square test presented as 0.006. Finally, for CBL between supra and equicrestal placement, WMD was -0.64 mm (p<0.0001), favoring the supracrestal group. For tissue level implants, WMD of early and late CBL in implants placed equi-crestally was 0.68±0.12mm and 0.69±0.54mm, respectively, where for implants placed sub-crestally, the WMD of CBL was 1.72±0.15mm and 2.26±0.63mm, respectively.

Conclusions: Within the limitations of this study, it is recommended to place tissue level implants equicrestally, and bone level implants subcrestally.

Keywords: Dental implant, bone remodeling, clinical study, systematic, review.

Introduction

The root causes of crestal bone loss (CBL) around dental implants is a topic that is often challenged, and although the literature is dwelled with articles debating the topic, a verdict is yet to be reached [1, 2]. This is particularly true since the exact reasons behind CBL and the determinant factors upon which its magnitude fluctuates is still uncertain [2-4]. It is known beforehand that if CBL is controlled, good esthetic outcomes can be sustained [5], and the likelihood of metal showing can be decreased [6,7]. Crestal bone stability is usually considered a sign of implant success [8], presence of CBL in early stages is considered an indication of further bone loss progression [9], and CBL is often considered the first step preceding peri-implantitis [10]. Previously, studies investigating CBL could not differentiate early bone loss following surgical implant placement from bone remodeling resulting from biologic width formation after implant exposure to the oral cavity, apart from a disease process leading to peri-implantitis [11, 12]. All stated forms of CBL were regarded as a single entity, a part of the "physiologic/inevitable" CBL after implant placement [13]. Such differentiation is indispensable, for if we wish to control the initial physiologic response exhibited in CBL, we must know what caused it first-hand [2].

Considering the key importance of CBL to implant success, several preclinical and clinical studies have investigating a variety of confounding biologic, technical, or biomechanical factors that could contribute to this phenomenon [1]. Once any confounding factor is identified, implant manufacturers rush to incorporate innovative implant features, and even surgical protocols, to accommodate the newly identified considerations [14]. Contributing factors include surgical manipulation of implant site [15], establishment of biologic width [16], foreign body reaction to titanium [17], reduced thickness of buccal bone [18] and reduced thickness of soft tissue [19, 20] at implant site. Meanwhile, designs and surgical modifications suggested to overcome these shortcomings included: platform switching [21], increasing the soft tissue thickness at the implant site [22], using regular and reduced implant diameters [23], and changing the implant-abutment junction position to the alveolar bone crest [24].

Specifically, the position of implant-abutment junction (IAJ) with regard to the crestal bone has been regularly surveyed [25], postulating the notion that once an ideal apico-coronal implant position is acquired, minimum CBL will occur and a perfect, harmonious emergence profile could exist. The main proposition is usually based on the detrimental effects microgap has on the adjacent crestal bone [26]. By definition the microgap is located at the IAJ which, with exception of soft tissue level implants, is located at the same level as crestal bone. Observing the behavior of crestal bone adjacent to IAJ suggests that strong inflammatory stimuli originate at the implant-abutment interface, and that there is a causal relationship between the degree of inflammation and the magnitude of CBL [27]. Thus, according to this postulation, if the microgap was placed away from crestal bone, only minimal bone loss will occur [28, 29]. Several authors recommended placing IAJ subcrestally to avert anticipated bone loss, thus maintaining maximum implant bone level, and subsequently maintaining the initial soft tissue levels [29, 30]. This opinion is now gaining more popularity; particularly after human histological evidence presented in some studies [31]. This clearly contradicts the mainstream classic literature [32, 33], and manufacturers' recommendations; where both advocate placing implants at the same level of crestal bone (equicrestally) is advocated. Nevertheless, other studies recommend placing IAJ above the level of crestal bone (supracrestally), leaving a portion of the implant's machined/rough surface exposed [28,34,35]. This again was suggested to safeguard the supporting crestal bone from the detrimental effects of the microgap [36]. As previously mentioned, the position of IAJ is a product of implant design, and therefore, we ought not to expect resemblance in neither the magnitude and timing of CBL [37], nor the dimensions of biologic width to be the similar to bone level implants [38].

In 2014, a systematic review investigating few animal and human studies, took into consideration the potential effect of implant–abutment configuration and the positioning of the microgap on CBL. Unfortunately, the results were inconclusive due to shortage of relevant studies [39]. Since then, numerous studies were published, investigating the effect of different apico-coronal implant positions on CBL. Hence, the aim of the current study was to investigate the possible association

between the apico-coronal position of IAJ and early and late CBL, in different implant configurations.

Methods

- **Objective of the review**

The objective of this review was to address the following focused questions:

1) Does the apico-coronal position of IAJ affect early and late CBL?

2) Since IAJ position changes with different implant configurations, will there be a difference in CBL between bone and tissue level implants?

The focused question was built to aid searching through the literature, the question was founded in the *PICO* format [40], where **Population(P)**: participants with osseointegrated implants; **Intervention(I)**: position of IAJ to crestal bone; **Comparison(C)**: implants placed in a different position than the intervention, and **Outcome(O)**: crestal bone loss.

Population

The *population* of interest consisted of healthy people with missing teeth which were replaced by restored dental implants in healed alveolar ridges, and placed in completely or partially edentulous, mandibular or maxillary dental/alveolar arches.

Intervention

Implant placement at any apico-coronal (vertical) position to the crestal bone was considered our *intervention*. These include implants placed with the IAJ at the same level of the crest (Equicrestal), below the level of crestal bone (Subcrestal), and above the level of crestal bone (Supracrestal).

Comparison

Only studies that reported results of a *comparison (control)* implants which were placed in a different apico-coronal position than the intervention were included in this review. These included randomized and non-randomized controlled clinical trials.

Outcome

The *outcomes* were development of crestal bone loss around dental implants, as assessed by radiographic follow up. In order to standardize the definition of CBL to eliminate possible bias arising from using different definitions, studies investigating CBL were segregated into an early, and late CBL groups. Early CBL was defined as bone loss occurring after implant placement but before its restoration. A follow up period for early bone loss was chosen to be a maximum of 6 months. Late bone loss was defined as bone remodeling occurring after implant restoration, a follow up period for that was chosen to be at least 12 months.

Information sources for data extraction:

Electronic and manual literature searches were conducted independently by two authors (AR & FA) in multiple databases including MEDLINE (OVID), EMBASE (OVID) and Cochrane Central Register of Controlled Trials (Cochrane Library) for reports published up to April 2016 without any language restrictions. Moreover, the grey literature at the New York Academy of Medicine Grey Literature Report (http://greylit.org) and the register of clinical studies hosted by the US National Institutes of Health (www.clinicaltrials.gov) were searched to further identify potential candidates for inclusion. Additionally, a manual search of periodontics- and implantology-related journal issues was performed*: Journal of Dental Research, Journal of periodontology, Journal of clinical periodontology, International Journal of Periodontics & Restorative Dentistry, Clinical Oral Implants Research, International Journal of Oral and Maxillofacial Implants and Clinical Implant Dentistry and Related Research.* Furthermore, reference lists/bibliographies of all candidate full-text articles were searched. Finally, three experts in the field were consulted whether any additional reports can be included to our final search results. Reports in languages other than English, Italian and Spanish were translated by a native speaker of the corresponding foreign language for inclusion/exclusion determination.

- Literature screening process:

For the PubMed library search strategy, a combination of (MeSH and EMTREE) keywords were used for PubMed library: (((((("dental implants"[MeSH Terms] OR ("dental"[All Fields] AND "implants"[All Fields]) OR "dental implants"[All Fields]) OR (("titanium"[MeSH Terms] OR "titanium"[All Fields]) AND ("dental implants"[MeSH Terms] OR ("dental"[All Fields] AND "implants"[All Fields]) OR "dental implants"[All Fields]))) AND (implant-abutment[All Fields] AND connection[All Fields])) OR (machined[All Fields] AND collar[All Fields])) OR microgap[All Fields]) OR (implant[All Fields] AND abutment[All Fields] AND connection[All Fields])) OR (crestal[All Fields] AND ("bone and bones"[MeSH Terms] OR ("bone"[All Fields] AND "bones"[All Fields]) OR "bone and bones"[All Fields] OR "bone"[All Fields]) AND level[All Fields])) AND ("1990/01/01"[PDAT] : "2017/05/27"[PDAT]) AND "humans"[MeSH Terms]. For EMBASE the key words were 'dental'/exp OR dental AND ('implants'/exp OR implants) OR 'titanium'/exp OR titanium AND ('dental'/exp OR dental) AND ('implants'/exp OR implants) AND 'implant abutment' AND ('connection'/exp OR connection) OR machined AND ('collar'/exp OR collar) OR microgap OR 'implant'/exp OR implant AND abutment AND ('connection'/exp OR connection) OR crestal AND ('bone'/exp OR bone) AND level AND [1-1-1990]/sd NOT [27-5-2017]/sd AND [1990-2017]/py. The screening of these database was limited to “humans”. Potential articles were examined by two reviewers (AR and FA) and inclusion was assessed after discussion. The level of agreement between both reviewers was determined by free-marginal kappa scores (Figure 1).

- Eligibility Criteria

During the first step of selection, studies were accounted eligible for inclusion in this systematic review if they met the following criteria: 1) Original prospective controlled clinical trials, 2) Human studies, 3) Overall inclusion of ≥ 10 implants in each group, 4) Radiographic follow-up of a maximum of 6 months after implant placement for submerged non-loaded implants (early remodeling measurement), 5) Radiographic follow-up of at least 12 month after abutment connection (delayed remodeling measurement), 6) Bone-level and tissue-level implants 7) All

known languages 8) Published in an international peer reviewed journal. At the second stage, the following exclusion criteria were employed: 1) In vitro studies 2) Immediately placed implants. 3) Non-responding authors for missing data 4) Double published articles. 5) Articles not mentioning bone remodeling as an outcome. 5) Locally or systemically compromised sites and/or conditions. 6) Retrospective studies, non-controlled prospective studies.

- Data extraction & analyses

First, studies were retained based on data from screening of the title and abstracts, later the final stage of screening involved full-text reading by two reviewers (MS and AR) using a predetermined data extraction form to confirm the eligibility of each study based on the inclusion and exclusion criteria. During each stage, any disagreement was resolved by discussion with a third reviewer (FS).

- Reporting format

The PRISMA-P checklist (supplemental Checklist 1) was followed for protocol preparation of this systematic review [41]. All review methods were established entirely prior to the conduct of the review. The 27-item Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement statement [42] was used to describe and summarizing the results of search progression, the screening process based on the PRISMA guidelines can be seen in Figure 1. This study followed the Assessment of Multiple Systematic Reviews guidelines (AMSTAR) [43] to achieve the standards of reporting systematic reviews. Since this systematic review included both randomized controlled trials (RCTs) and non-randomized studies of healthcare interventions (NRSI), the AMSTAR 2 tool was used for self-evaluation and supplementary guidance [44], where rating the overall confidence in the results of this review was high.

- Quality assessment of selected studies

Quality assessment was based on the published full-text article and was performed independently by two investigators (MS and AR) Any disagreements were resolved by discussion with a third investigator (FS). The assessment was performed in three separate phases. During phase I, a quality assessment of included articles [45,46] of all selected full-text articles was performed according to the

revised recommendations of the CONSORT statement for evaluation of randomized controlled trials (Schulz et al. 2010). A predefined scoring system was used for the quality assessment of finally selected clinical studies [47]. Based on the CONSORT statement, a 25-point assessment examining 1) Title and introduction; 2) Methods; 3) Results; 4) Discussion and 5) Other information, was completed for all selected studies (Supplementary Table 1). For phase II of the assessment, any supplemental materials associated with the publication were examined, and disagreements at this point were resolved by discussion.

In phase III, an overall estimation of the plausible risk of bias (low, moderate, or high) was performed for the selected studies. A low risk of bias was estimated when all of the criteria were met. A moderate risk was considered when one or more criteria were partly met, while a high risk of bias was estimated when one or more criteria were not met (Cochrane Handbook for Systematic Reviews of Interventions, version 5.1.0., http://www.cochrane.org/resources/handbook) [48]. The evaluated parameters included: 1) Random sequence 2) Generation allocation concealment 3) Blinding participants 4) Blinding outcome assessment 5) Incomplete outcome data addresses 6) Selective outcome reporting 7) Other biases. The potential risk of bias was categorized as high if a study showed missing information of >2 parameters, a moderate risk was considered if a study failed to provide information on only one of the parameters and low if a study provided detailed information about all the parameters (Figure 2).

- Statistical analyses:

The primary outcome was the amount of CBL. The pooled weighted mean difference (WMD) of CBL between various implant placement protocols (supra-, sub- and equi-crestal) at the timing of before and after abutment connection, were estimated using a computer program (RevMan Version 5.0. Copenhagen; The Nordic Cochrane Centre, The Cochrane Collaboration, 2008). To avoid potential bias of combining the internal hex abutment and Morse taper connection, these abutment types were pooled separately as subgroup analyses. The contribution of each article was weighed. Random effects meta-analyses of the selected studies were performed to avoid any bias being

caused by methodological differences between studies. Forest plots were produced to graphically represent the difference in outcomes of for all included studies using dental implant as the analysis unit. A p value= 0.05 was used as the level of significance. Heterogeneity was assessed with chi-square test and I2 test, which ranges between 0% and 100% and lower values representing less heterogeneity. In addition, the weighted mean (WM) and the standard deviation of CBL in each subgroup were also calculated using another computer program (Comprehensive Meta-Analysis Version 2, Biostat, Englewood, NJ, USA).

Results

- Study protocol

The search and data extraction was done in adherence with the study protocol with no deviations. Search of titles, abstracts, and full-text articles, as well as the quality of selected studies were independently reviewed by two reviewers using a standard method to enable us from appraising our internal validity.

- Study Selection

Initial screening yielded a total of 1442 articles (885 PubMed, 532 EMBASE). Additionally, 23 more articles were found through manual screening. Overall, 1065 potentially relevant articles were selected after an evaluation of their titles and abstracts, of which, 31 full texts of these articles were obtained and thoroughly evaluated. Of these, 14 articles fulfilled the inclusion criteria and were included in the qualitative synthesis. A total of 1034 articles were excluded. Out of the 14 articles included in the systematic review, 12 were included in the quantitative synthesis and meta-analyzed to extract the influence of the variables on CBL. Figure 1 depicts the screening process based on the PRISMA guidelines and the supplementary Table 2 shows the exclusion justification for any study after full-text evaluation. The *k* value for inter-reviewer agreement for potentially relevant articles was 0.87 (titles and abstracts) and 0.93 (full-text articles), indicating a consistent agreement between the two reviewers.

- **Characteristics of selected Studies**

Eight articles were RCTs [37, 49-55], 4 were comparative controlled trials [56-59], and 2 were prospective cohorts [60,61]. Of the 12 articles included in the meta-analysis, 3 measured early CBL in bone level implants [54,58,61], 7 recorded late remodeling bone level implants [49-53,57,59], and 2 in tissue level implants [56,60]. Details of all included studies are summarized in tables 1 and 2.

- **Findings based on our previous focused questions:**

1- Is there an association between the apico-coronal position of IAJ with regard to early and late CBL?

A) WMD of CBL between equicrestal and subcrestal placement before abutment connection

Three studies [54,58,61] reported data on CBL of implants placed equi-crestally and sub-crestally before abutment connection. One study [61] used Morse taper cone connection abutment whereas another one (58) used internal hex abutment. The third, [54] used both configurations of implant-abutment connection. The WMD was 0.30 mm (95% CI= -0.12 to 0.72, p= 0.16) and -0.11 mm (95% CI= -0.15 to -0.07, $p< 0.0001$, favoring subcrestal placement) for Morse taper and internal hex subgroups, respectively (Figure 3). The overall analysis presented a WMD of 0.15 mm (95% CI= -0.07 to 0.36, $p= 0.18$). However, the comparison presented a considerable heterogeneity among studies for Morse taper subgroup and the overall analysis; the *p* value for chi-square test presented as <0.0001 and <0.0001, respectively. For internal hex subgroup, the *p* value for chi-square test was 0.62, representing a low heterogeneity.

B) WMD of CBL between equicrestal and subcrestal placement after abutment connection

Six studies [50-53,57,59], reported data on CBL of implants placed equi-crestally and sub-crestally after abutment connection (mean 18.64 months). Five studies [50-53,59] used Morse taper abutment and the remaining study [57] used internal hex abutment. However, Veis et al. 2010 [57] introduced straight and platform switching abutment designs as study arms, therefore, these two arms were pooled separately. The WMD was 0.30 mm (95% CI= -0.15 to 0.75, p= 0.19) and -0.59 mm (95% CI= -0.90 to -0.28, p= 0.0002, favoring subcrestal placement) for Morse taper and internal hex

subgroups, respectively (Figure 4). The overall analysis presented a WMD of 0.03 mm (95% CI= -0.34 to 0.40, p= 0.88). However, the comparison presented a considerable heterogeneity among studies for Morse taper subgroup and the overall analysis; the *p* value for chi-square test presented as <0.0001 and <0.0001, respectively. For internal hex subgroup, the *p* value for chi-square test was 0.11, representing a moderate heterogeneity.

C) **WMD of CBL between supracrestal and subcrestal placement after abutment connection**

One study [57] reported data on CBL of supracrestal and subcrestal implants, using internal hex abutment after abutment connection. This study [57] had straight and platform switching abutment designs as two separate study arms, therefore, these two arms were pooled. The WMD was 0.04 mm (95% CI= -0.46 to 0.54, p= 0.86, Figure5). The comparison presented a considerable heterogeneity between these two arms where the *p* value for chi-square test presented as 0.006.

D) WMD of CBL between supracrestal and equicrestal placement after abutment connection

Two studies [49,57] reported data on CBL of supracrestal and equicrestal implants, using internal hex abutment after abutment connection. Again, since one study [57] had straight and platform switching abutment designs as two separate study arms, therefore, these two arms were pooled separately. The WMD was -0.64 mm (95% CI= -0.92 to -0.35, p< 0.0001, Figure 6), favoring supra-crestal group. The comparison presented a moderate heterogeneity among the studies where the *p* value for chi-square test presented as 0.07.

2- Is there a difference in CBL between bone and tissue level implants?

A) Tissue level implants

In terms of the studies using tissue level implants, none reported the CBL outcome when implants were placed supracrestally. For the implants placed equicrestally, the WM of CBL before and after abutment connection was 0.68±0.12mm and 0.69±0.54mm, respectively. For the implants placed subcrestally, the WM of CBL before and after abutment connection was 1.72±0.15mm and 2.26±0.63mm, respectively.

B) WM of CBL for each subgroup

The WM of CBL for each subgroup is reported in table 3. For the studies using bone level implants, the WM of CBL before and after abutment connection, when placed supracrestally, was 0.03±0.30mm and 0.66±0.11mm, respectively. For the implants placed equicrestally, the WM of CBL before and after abutment connection was 0.57±0.29mm and 0.80±0.30mm, respectively. For the implants placed subcrestally, the WM of CBL before and after abutment connection was 0.52±0.14mm and 0.57±0.19mm, respectively. All results based on different configurations are shown in table 3.

- **Quality Assessment**

Only 4 studies [52-55] reported their articles in concordance with the CONSORT statement [47]. It is also worth mentioning that 4 studies were conducted before the CONSORT publication was available. Quality assessment of studies was performed as per the checklist item of (CONSORT) (Supplementary table 1). Majority of publications were particularly correlated with minimum scores when evaluating checklist items. When studies conducted before the CONSORT were compared to other studies, most compared items were not found to be equally adequate. Moreover, with risk of bias, they scored the highest (Figure 2).

Discussion

This review was designed to evaluate CBL with the IAJ at different positions relative to the bone crest. Our investigation distinguished between two incidents of CBL. The first, occurring after surgical placement of an implant and before abutment connection. The second, which is after abutment connection and the succeeding functional loading. These two instances were segregated in an attempt to differentiate between an early bone loss that might occur post surgery as a result of poor implant design, construction or placement by untrained clinicians, and a later bone loss that takes place due to bacterial leakage from the microgap, formation of biologic width or overloading amongst other reasons [62-64].

For bone level implants, our results revealed that prior to abutment connection, a subcrestal IAJ position offers slightly less CBL than both a supracrestal and an equicrestal position, though, differences were not statistically significant. In contrast, after abutment connection, the least amount of CBL occurred when IAJ was placed supracrestally, and this result demonstrated otherwise to be statistically significant. Regarding tissue level implants, due to inherent implant design, the concept of different occurrences of remodeling based on abutment connection was not sensible. More late CBL was observed around implants were placed subcrestally versus equicrestally, where a statistical significance was found too. Contrarily, our results proposed that a subcrestal position leads to increased CBL than equicrestal position in tissue level implants.

Since the included studies comprised different implant designs, with varying configurations of implant-abutment connection, subsequent groups of results were pooled according to connection type. However, when doing so, all results were not found to be statistically significant.

When compared to bone level implants, tissue level implants have utterly different bounds [65]. Tissue level implants are typically formed of a rough fixture surface and a relatively smooth collar, and behave biologically much similar to one-piece implants. In the original surgical protocol, it was recommended that the rough-to-smooth margin is placed at the level of the bone crest [66]. This protocol presents an obvious biological advantage, but otherwise an esthetic detriment. The IAJ, and thus the microgap, are quite coronal from the crestal bone, which keeps crestal bone relatively protected [29]. This position also results in a crown margin with an equigingival location, rendering in an easier hygiene control. On the other hand, the smooth collar is a compromise in esthetic zones; to keep it obscured subgingivally in preparation for unexpected facial bone loss, placing the rough-to-smooth border 1 mm subcrestally was suggested [6,67]. In this case, a polished titanium surface that does not promote osseointegration will be in direct bone contact, resulting in a gradual resorption of adjacent bone [56,60].

Similarly, a subcrestal implant position was proposed in bone-level implants to improve esthetic results by yielding a sized running room for abutment and restoration. This, in turn, delivers an

improved emergence profile and thus, an overall pleasing esthetic result [68]. Vis-a-vis biologic consequences, if bone loss occurs, the exposed rough implant surface will facilitate plaque accumulation, and, therefore, possibly predispose to peri-implant disease [69]. Though, at an early stage, judgment can be challenging, where no distinction exists between increased CBL and commencement of peri-implant disease except for more specific clinical signs [10].

Since this is the first systematic review and meta-analysis discussing the topic through such approach, it is may be challenging to directly compare it with other studies; though some aspects of the study may still be compared with previous reviews [25,39]. The first review examined late bone loss in specific situations for various implant configurations. Amongst the studies the first review examined, a total of 11 studies, among which only 3 are human, discussed the effect of IAJ position on CBL. The study results supported equicrestal placement of tissue level implants, where a subcrestal position was suggested for bone level implants [39]. The second review discussed late bone loss in tissue versus bone level implants placed only in an equicrestal position. Four studies were selected for conducting the systematic review and meta-analysis. The study concluded that bone level implants suffered less late CBL than tissue level implants [25].

One of the limitation of our results is that it does not apply to immediately placed implants. A CBCT study by Chappuis and coworkers [70] reported that after tooth extraction, mean progressive bone resorption of facial bone was 48.3%, versus merely 4.5% of interproximal alteration. This was later confirmed to result in more exaggerated facial bone loss in immediately placed implants [71]. The stark conclusions made by studies similar to the latter ones led us to exclude all studies investigating CBL after immediate implant placement from our search.

Another major limitation of this study is its inability to detect the facial bone loss and its impact on esthetic outcome. Several studies directly correlated CBL with the projected facial bone loss and subsequently with any effects that might have on esthetics. It is well demonstrated that peri-implant dimensional alterations are most manifested in facial bone. An average of 0.7–1.3mm reduction in buccal and lingual bone height, versus only 0.1 mm of proximal loss of bone height was reportedly

observed [3]. These findings could not have been just obtained via two dimensional periapical (PA) radiographs. It is thus a clear limitation of most studies included in this review, and almost all studies of similar nature, being dependent on PA radiographs as the select means of measuring CBL. Following the PA model leads to falling into two distinctive biases. The first is evidently that PA radiographs are incapable of measuring facial bone changes and thus their value is limited to interproximal crestal bone assessment. Second, knowing that the slightest vertical angulation might forfeit the reliability of CBL measurement, accuracy of measuring bone remodeling using PA's, though standardized, is questionable [72]. This means that, if held reliable, PA radiographs should only be useful for assessing inter-proximal bone changes rather than circumferential CBL [73]. Given that, one would assume using a CBCT to render the genuine CBL, including the key facial bone loss [74]. Yet inherent artifacts caused by titanium implants in CBCT scans decrease the visualization of bone-implant interface, making reliable assessment of facial and lingual bone inaccurate as well [75,76].

In the current investigation, a single study used CBCT for measuring CBL, and was accordingly able to measure facial and lingual bone changes [50]. Investigators in that study noticed that when implants were placed subcrestally, a 0% chance of crestal bone reaching a position apical to the IAJ existed; versus a 10% chance when implants were placed equicrestally. This was consistently true for implants placed both at 1mm, and 2 mm subcrestally. Similar results were earlier reported in animal studies [77]. If such an event occurs clinically in concordance with thin peri-implant soft tissue, exposure of the implant surface will be inevitable, eventually triggering It future biologic and esthetic concerns (Figure 7).

Soft tissue architecture facial to dental implants has been persistently used to evaluate the esthetic success of implant restorations [78,79], and was suggested to be determined by the underlying bony foundation [80]. Similarly, oral soft tissue biotype and soft tissue thickness at implant site [81-83] were shown to take part in etiology of CBL. A fact worth mentioning is that studies examining significance of soft tissue thickness in limiting CBL pointed out that placing implants supracrestaly

will not satisfy the minimum dimension required for formation of biologic width, consequently defeating the purpose of a protective biologic zone, and leading to increased CBL [20]. In the current review, only 1 study examined the effect of peri-implant tissue thickness on CBL, and found that significant reduction in CBL occurred when tissue thickness was ≥ 2mm [49].

Though our results demonstrate statistically significant differences according to IAJ location, we doubt if it holds any considerable clinical significance. Rather, a slightly subcrestal implant position seems to keep implant platform covered with bone at all instances after the remodeling process occurs.

This study was focused on the timing and magnitude of CBL with a premise of IAJ being a key factor behind it. Regardless of IAJ position, differences in CBL remained quite within 1mm. As timidly revealed by this review, soft tissue thickness around implants [49], as well as the configuration of implant-abutment connection [54], might have a more profound effect on CBL than the IAJ position, and should therefore be investigated more meticulously through well designed, minimally-biased RCTs.

Recommendations for future studies

Although it might not be possible to blind the clinicians, blinding of the outcome assessors is suggested for any future research. Additionally, decreased heterogeneity and control of bias sources are strongly recommended. There is also an urgent need to find a more reliable, objective and reproducible method to measure facial bone changes around dental implants. Future studies might need to focus on the effect of implant-abutment connection and soft tissue thickness around implants on CBL.

Conclusions

With the aforementioned limitations and the high risk of bias found in the studies included in this review, the following conclusions can be cautiously drawn:

I) In bone level implants, the association between the apico-coronal position of the IAJ and CBL is statistically insignificant in all configurations except when supracrestal IAJ is compared to equicrestal. Rather, all results were found to be clinically insignificant.

II) There is a difference in the behavior of tissue level implants compared to bone level implants. Equicrestal placement of IAJ produces significantly less CBL than the subcrestal placement in tissue level implants.

III) Very limited evidence proposes that a subcrestal position of the IAJ might keep implant threads covered by bone after early and late CBL occurs.

IV) Approximately 1mm of CBL is expected after implant placement as a result of bone remodeling.

Ethical approval

Not required.

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Tables and Figures:

Figures

Figure 1: PRISMA flowchart of the screening process in the different databases

Figure 2: Risk of bias assessment

Figure 3: WMD of CBL between equicrestal and subcrestal placement before abutment connection.

Figure 4: WMD of CBL between equicrestal and subcrestal placement after abutment connection.

Figure 5: WMD of CBL between supracrestal and subcrestal placement after abutment connection in internal hex.

Figure 6: WMD of CBL between supracrestal and equicrestal placement after abutment connection in internal hex.

Figure 7: An illustration comparing CBL at implant placement, after early and late remodeling.

Tables

Table 1: Characteristics of studies comparing early CBL

Table 2: Characteristics of studies comparing late CBL

Table 3: Results by main groups

Supplemental material:

***S* Table 1:** Quality assessment of included studies according to the CONSORT statement

***S* Table 2:** Characteristics of excluded studies

***S* Checklist 1:** PRISMA-P 2015 checklist

Table 1: Characteristics of studies comparing early CBL

(Excel sheet sent separately)

Table 2: Characteristics of studies comparing late CBL

(Excel sheet sent separately)

Table 3: Results by main groups

	Bone level implants	Tissue level implants
Supracrestal before abutment connection	0.03±0.30mm	N/A
Supracrestal after abutment connection	0.66±0.11mm	N/A
Equicrestal before abutment connection	0.57±0.29mm	0.68±0.12mm*
Equicrestal after abutment connection	0.80±0.30mm	0.69±0.54mm
Subcrestal before abutment connection	0.52±0.14mm	1.72±0.15mm
Subcrestal after abutment connection	0.57±0.19mm	2.26±0.63mm

Supplemental table 1:

Author, Year	Title & Introduction		Methods										Results							Discussion			Other information		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Al Amiri *et al.*[52]	I	A	I	A	A	I	I	A	A	I	I	A	A	I	I	A	A	A	I	A	A	A	A	I	A
Cassetta *et al.*[61]	I	A	I	I	A	A	I	I	I	I	I	A	I	I	I	A	A	I	I	I	A	A	I	I	A
de Siqueria *et al.*[53]	A	A	A	A	A	A	I	A	A	I	I	A	A	A	I	A	A	A	I	A	A	A	A	I	I
Fernandez *et al.*[37]	A	A	I	A	A	I	I	A	A	I	I	I	I	A	I	A	A	A	I	A	A	A	I	I	I
Gualini *et al.*[55]	A	A	A	A	A	A	I	A	A	I	I	I	A	I	I	A	A	I	A	I	A	I	I	I	I
Hämmerle *et al.*[56]	I	A	I	A	A	I	I	I	I	I	I	A	A	I	I	A	I	A	I	A	A	A	I	I	A
Hartman *et al.*[60]	I	A	I	I	I	I	I	I	I	I	I	I	I	I	I	I	A	A	I	A	I	A	I	I	I
Koutouzis *et al.*[50]	I	A	I	A	A	A	I	A	A	A	I	A	A	I	I	A	A	A	I	A	A	A	I	I	A
Kütan *et al.*[51]	A	A	A	A	A	A	I	A	A	A	A	A	A	A	I	A	A	A	A	A	A	A	I	I	I
Linkivicius *et al.*[49]	I	A	I	A	A	A	I	I	I	I	I	A	I	I	I	A	I	I	I	I	A	A	I	I	I
Nagarajan *et al.*[58]	I	A	I	A	A	I	I	I	I	I	I	A	A	I	I	A	A	A	I	I	A	I	I	I	I
Palaska *et al.*[54]	A	A	I	A	A	I	I	A	A	A	I	A	A	A	A	A	A	A	I	A	A	A	I	I	I
Pellicer *et al.*[59]	I	A	I	A	A	A	I	I	I	I	I	A	I	A	I	A	I	I	I	I	I	A	A	I	I
Veis *et al.*[57]	I	A	I	I	I	I	I	I	I	I	I	A	I	I	I	A	A	A	I	I	A	I	I	I	I

Supplemental table 2: Reasons for exclusion

Reason for exclusion	Author/Year
Distance to bone level not specified in mm bone level	Fickl et al, 2010; Goswami et al, 2009; Kadkhodazadeh et al, 2013, Stein et al, 2009
Implants placed at the same crestal position	Aimetti et al, 2015; Lee et al, 2010; Peñarrocha-Diago, 2013; Shin et al, 2006
Primary results of a follow up included study	Koutouzis et al, 2013

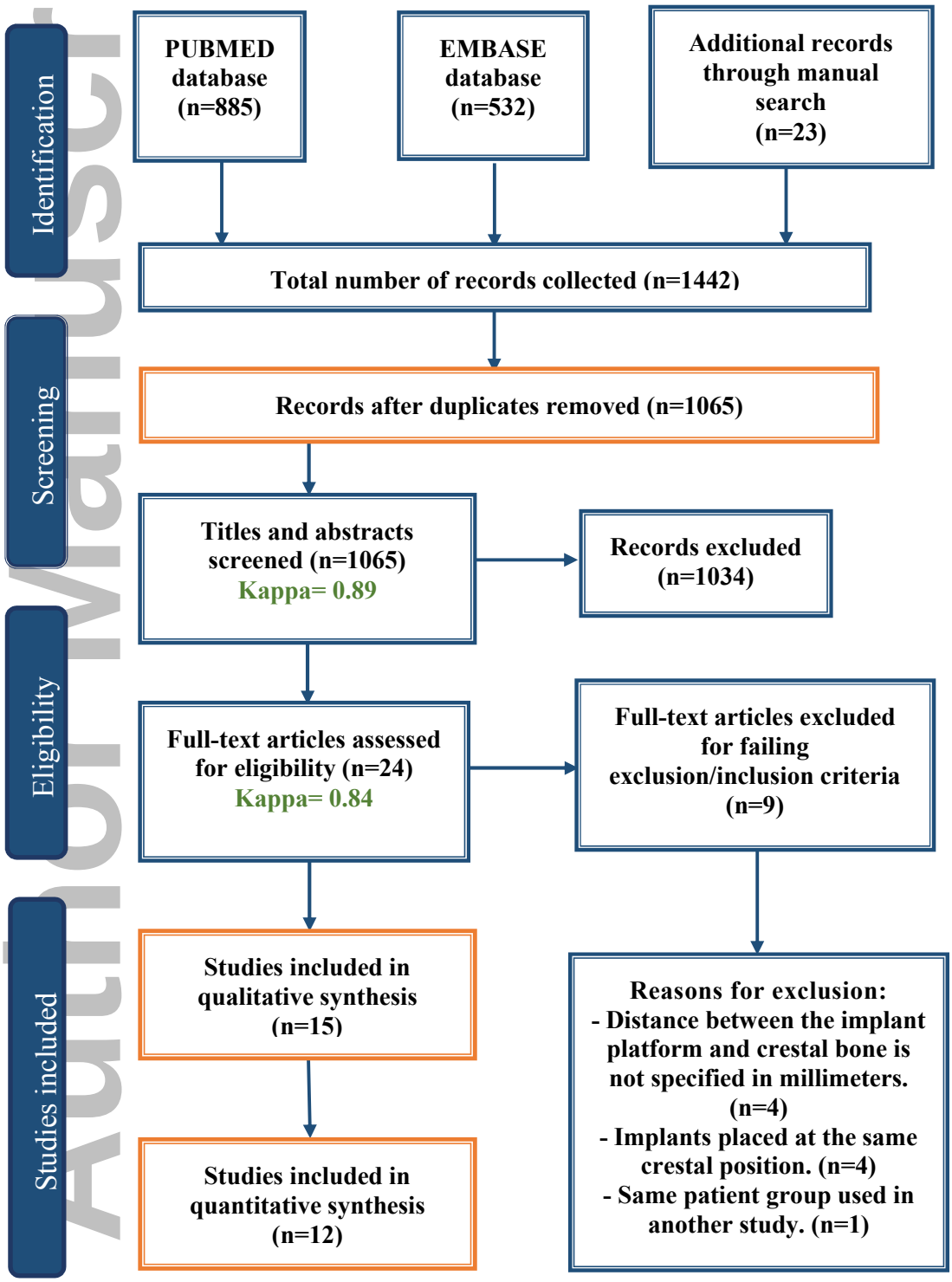
Supplemental Check list 1:

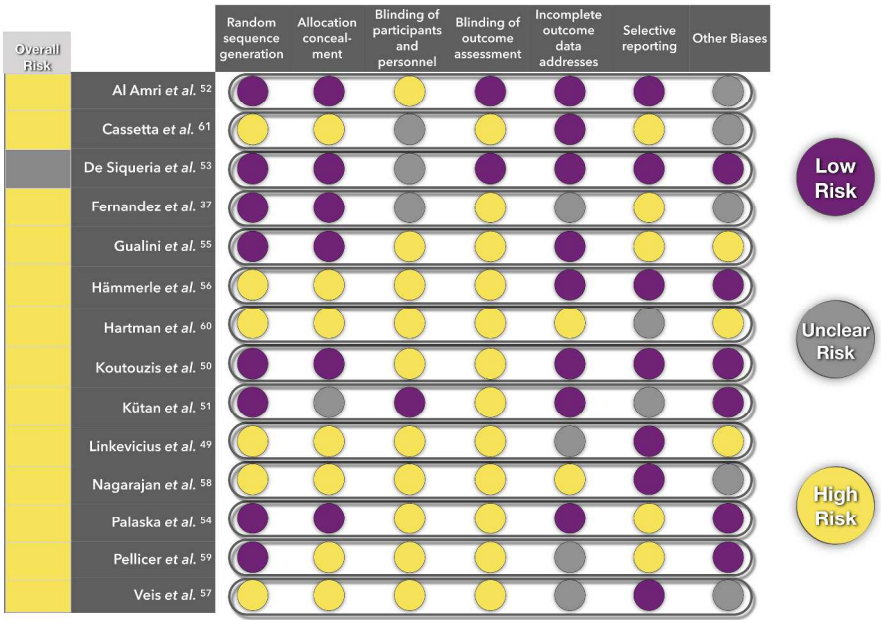
Section/topic	#	Checklist item	Information reported		Line number(s)
			Yes	No	
ADMINISTRATIVE INFORMATION					
Title					
Identification	1a	Identify the report as a protocol of a systematic review	☒	☐	
Update	1b	If the protocol is for an update of a previous systematic review, identify as such	☐	☒	
Registration	2	If registered, provide the name of the registry (e.g., PROSPERO) and registration number in the Abstract	☐	☒	
Authors					
Contact	3a	Provide name, institutional affiliation, and e-mail address of all protocol authors; provide physical mailing address of corresponding author	☒	☐	
Contributions	3b	Describe contributions of protocol authors and identify the guarantor of the review	☐	☒	
Amendments	4	If the protocol represents an amendment of a previously completed or published protocol, identify as such and list changes; otherwise, state plan for documenting important protocol amendments	☐	☒	
Support					
Sources	5a	Indicate sources of financial or other support for the review	☒	☐	
Sponsor	5b	Provide name for the review funder and/or sponsor	☒	☐	
Role of sponsor/funder	5c	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol	☐	☒	
INTRODUCTION					
Rationale	6	Describe the rationale for the review in the context of what is already known	☒	☐	
Objectives	7	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)	☒	☐	
METHODS					
Eligibility criteria	8	Specify the study characteristics (e.g., PICO, study design, setting, time frame) and report characteristics (e.g., years considered, language, publication status) to be used as criteria for eligibility for the review	☒	☐	

Section/topic	#	Checklist item	Information reported		Line number(s)
			Yes	No	
Information sources	9	Describe all intended information sources (e.g., electronic databases, contact with study authors, trial registers, or other grey literature sources) with planned dates of coverage	☒	☐	
Search strategy	10	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated	☒	☐	
STUDY RECORDS					
Data management	11a	Describe the mechanism(s) that will be used to manage records and data throughout the review	☒	☐	
Selection process	11b	State the process that will be used for selecting studies (e.g., two independent reviewers) through each phase of the review (i.e., screening, eligibility, and inclusion in meta-analysis)	☒	☐	
Data collection process	11c	Describe planned method of extracting data from reports (e.g., piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators	☒	☐	
Data items	12	List and define all variables for which data will be sought (e.g., PICO items, funding sources), any pre-planned data assumptions and simplifications	☒	☐	
Outcomes and prioritization	13	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale	☒	☐	
Risk of bias in individual studies	14	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used in data synthesis	☒	☐	
DATA					
Synthesis	15a	Describe criteria under which study data will be quantitatively synthesized	☒	☐	
	15b	If data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data, and methods of combining data from studies, including any planned exploration of consistency (e.g., I^2, Kendall's tau)	☒	☐	
	15c	Describe any proposed additional analyses (e.g., sensitivity or subgroup analyses, meta-regression)	☒	☐	
	15d	If quantitative synthesis is not appropriate, describe the type of summary planned	☐	☒	
Meta-bias(es)	16	Specify any planned assessment of meta-bias(es) (e.g., publication bias across studies, selective reporting within studies)	☒	☐	
Confidence in	17	Describe how the strength of the body of	☒	☐	

Section/topic	#	Checklist item	Information reported		Line number(s)
			Yes	No	
cumulative evidence		evidence will be assessed (e.g., GRADE)			

Figure 1: Screening process based on PRISMA guidelines.





1305x811mm (72 x 72 DPI)

Figure 3

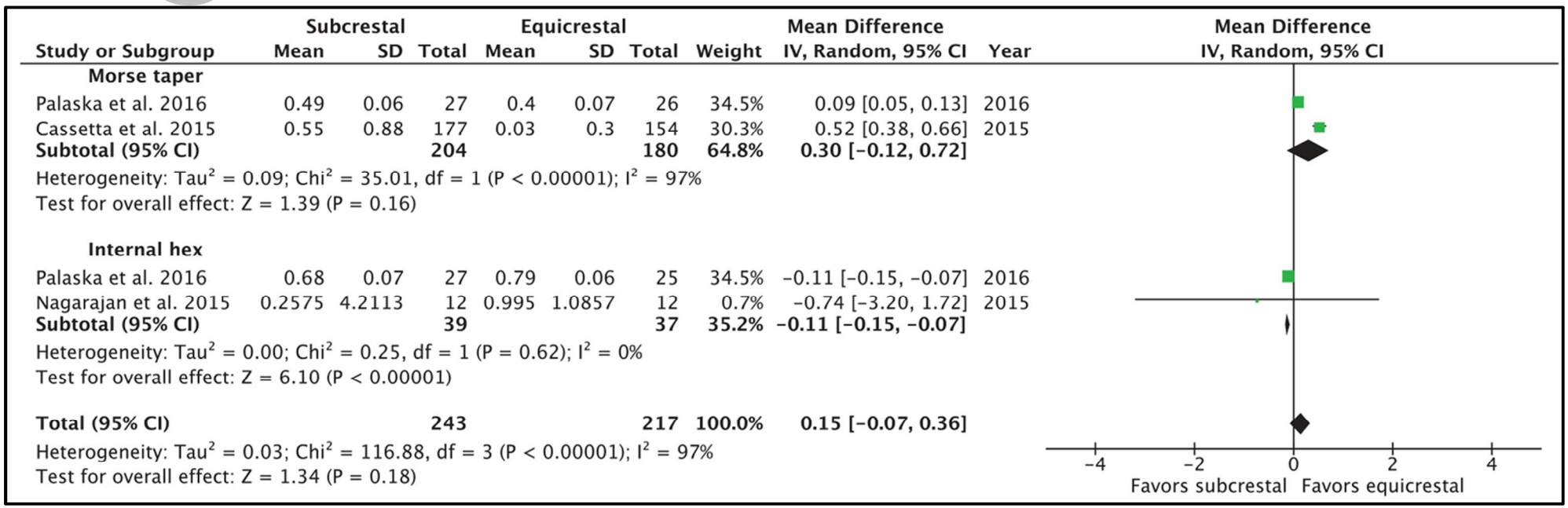


Figure 4

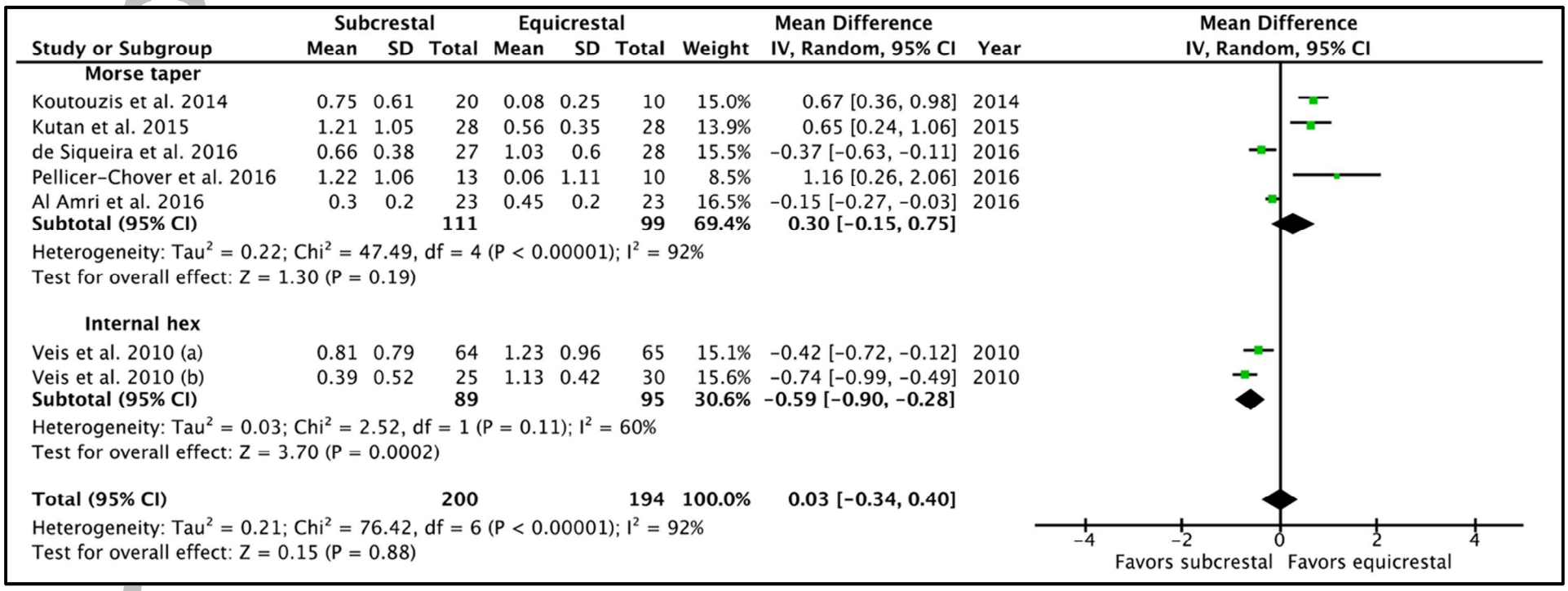


Figure 5

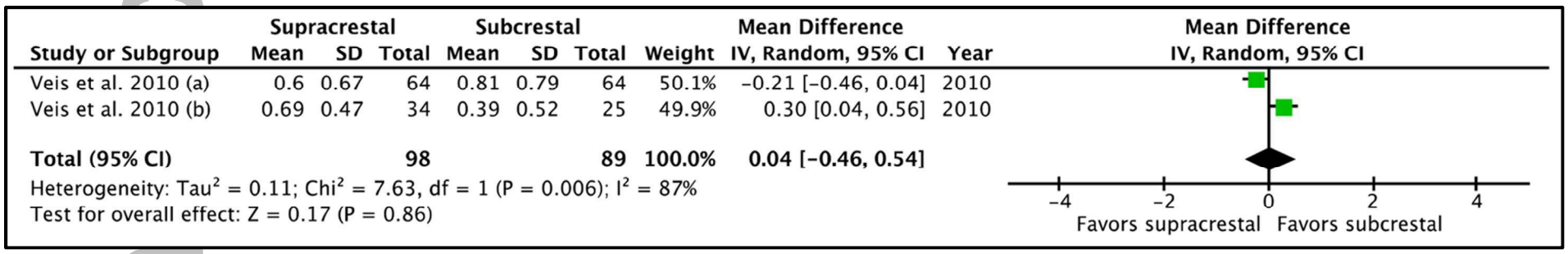
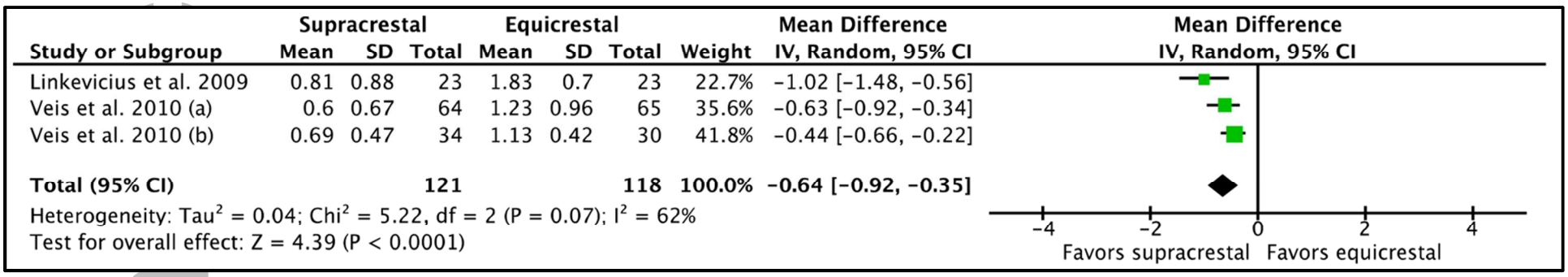


Figure 6



Implant Placement

Early Remodeling

Late Remodeling

Table 1 Characteristics of studies comparing early CBL

Study	Year	Country	Number of implants	Type of study	Implant type & manufacturer	Recommended IAJ position by manufacturer	Distance between IAJ and bone crest in the study	Surface treatment	Implant collar	Implant-abutment Connection	PFS	Implant diameter	Implant length	Includes smokers	Follow up	CBL	Healing abutment	CBL Assessment	Evaluation of peri-implant soft tissue thickness	Evaluation of soft tissue biotype	Reporting according to CONSORT
Equicrestal implant placement																					
Palaska *et al.* 54	2016	Greece	25	RCT	Biomet 3i; Certain prevail	Bone level	0mm	Dual acid etched with nano calcium phosphate deposits	Rough surface	Internal Hex	Yes	4mm	8.5 to 14mm	No	3 months	0.79mm± 0.06mm	Yes	Standardized PA	No	Yes, No statistically significant difference between thick and soft tissue biotypes	Yes
			26	RCT	Astra Tech; Osseospeed	Bone level	0mm	TiO blasted flouride treated	Rough surface with micro threads	Morse taper connecetion	Yes	3.5 to 5mm	8 to 13mm	No	3 months	0.40 mm± 0.07mm	Yes				
Cassetta *et al.* (2015)	2015	Italy	162	PC	Impladent; Osseothread	Bone level	0mm	SLA(Sand blasted Large grit Acid etched)	Rough surface	Morse taper connecetion	Yes	3.5 to 6.5mm	10, 12 & 14mm	NA	2 months	0.31mm± 0.64mm	No	Standardized PA	No	No	No
Nagarajan *et al.* (2015)	2015	India	12	PCC	Adin; Touareg	Bone level	0mm	SLA(Sand blasted Large grit Acid etched)	Rough surface	Internal Hex	Yes	N/A	N/A	No	6 months	1.31mm±1.04mm(mesial) & 0.68mm±1.08mm(distal)	No	Standardized PA	No	No	No
Subcrestal implant placement																					
Palaska *et al.* (2016)	2016	Greece	27	RCT	Biomet 3i; Certain prevail	Bone level	-1.5mm	Dual acid etched with nano calcium phosphate deposits	Rough surface	Internal Hex	Yes	4mm	8.5 to 13mm	No	3 months	0.68mm± 0.07mm	Yes	Standardized PA	No	Yes, No statistically significant difference between thick and soft tissue biotypes	Yes
			27	RCT	Astra Tech; Osseospeed	Bone level	-1.5mm	TiO blasted flouride treated	Rough surface with micro threads	Morse taper connecetion	Yes	3.5 to 5mm	8 to 13mm	No	3 months	0.49 ± 0.06mm	Yes				
Cassetta *et al.*(2015)	2015	Italy	177	PC	Impladent; Osseothread	Bone level	≤0.5mm	SLA(Sand blasted Large grit Acid etched)	Rough surface	Morse taper connecetion	Yes	3.5 to 6.7mm	10, 12 & 16mm	NA	2 months	0.55 ± 0.88	No	Standardized PA	No	No	No
Nagarajan *et al.* (2015)	2015	India	12	PCC	Adin; Touareg	Bone level	-1mm	SLA(Sand blasted Large grit Acid etched)	Rough surface	Internal Hex	Yes	N/A	N/A	No	6 months	0.49mm±0.49mm(mesial) & 0.02mm±6.06mm(distal)	No	Standardized PA	No	No	No

Table 2 Characteristics of studies comparing late CBL

	Study	Year	Country	Number of implants	Type of study	Implant type & manufacturer	Recommended IAJ position by manufacture	Distance between IAJ and bone crest in the study	Surface treatment	Implant collar	Implant-abutment Connection	Platform switched?	Implant diameter (mm)	Implant length (mm)	Includes smokers?	CBL	Type of restoration	Restoration retention	CBL Assessment	Evaluation of peri-implant soft tissue thickness	Evaluation of soft tissue biotype	Reporting according to CONSORT
Bone-level implants	**Equicrestal implant placement**																					
	Al Amiri et al. (2016)	2016	Saudi Arabia	23	SM-RCT	Straumann; Bone level RC	Bone level	0mm	SLA(Sand blasted Large grit Acid etched)	Rough surface	Morse taper	Yes	4.1mm	10, 12 & 14mm	No	0.45 ± 0.2mm	Single crowns	Screw	Standardized PA	No	No	Yes
	Pellicer-Chover et al.(2016)	2016	Spain	10	PCC	Mozo-Grau, Inhex	Bone level	0mm	Reabsorbable Blast Media	Rough surface with micro threads	Morse taper	Yes	4.2 & 5.0mm	10, 11.5 & 13mm	No	0.06 ± 1.11mm	Single crowns	Screw	Standardized PA	No	No	No
	Fernndez-Formoso et al. (2012)	2012	Spain	58	RCT	Straumann; Bone level	Bone level	0mm	SLA(Sand blasted Large grit Acid etched)	Rough surface	Morse taper	Yes	3.3, 4.1 & 4.8mm	8 & 14mm	No	0 68 ± 0 88mm	Single crowns	Cement	Standardized PA	No	No	No
	Veis et al. (2010)	2010	Greece	65	PCC	Biomet 3i; Full osseotite	Bone level	0mm	Dual Acid etched	Rough surface	Internal Hex	No	5mm	NA	NA	1.23 ± 0.96mm	NA	NA	Standardized PA	No	No	No
	Veis et al. (2010)	2010	Greece	30	PCC	Biomet 3i; Full osseotite	Bone level	0mm	Dual Acid etched	Rough surface	Internal Hex	Yes	5mm	NA	NA	1.13 ± 0.42mm	NA	NA	Standardized PA	No	No	No
	Kütan et al. (2015)	2015	Turkey	28	SM-RCT	Astra Tech, Osseospeed	Bone level	0mm	TiO blasted flouride treated	Rough surface with micro threads	Morse taper	Yes	3.5 & 4mm	9 & 13mm	No	0.56 ± 0.35mm	Single crown, splinted crowns & FPDs	Cement	Standardized PA	No	No	No
	Koutouzis et al. (2014)	2014	USA	10	RCT	Dentsply; Ankylos CX	Bone level (subcrestal optional)	0mm	Acid etched sand blasted	Acid etched sand blasted	Morse taper	Yes	NA	NA	No	0.08 ± 0.25mm	Single crowns	Screw	CBCT	No	Yes No statistically significant correlations between buccal mucosa thickness and CBL..	No
	De Siqueira et al. (2016)	2016	Brazil	28	RCT	Neodent; Titamax CM	Bone level	0mm	Acid etched sand blasted	Acid etched sand blasted	Morse taper	Yes	NA	NA	NA	1.03 ± 0.60mm	Hybrid Prosthesis	Screw	Standardized PA	Yes Soft tissue recession was not significantly influenced by vertical tissue thickness. Correlation between CBL & vertical tissue thickness was not assessed.	No	Yes

	Linkevicius et al. (2009)	2009	Lithuania	23	RCT	BioHorizons; Prodigy	Bone level (supracrestal optional)	0mm	Resorbable Blast Textured	1.5 mm rough laser-lok surface	Internal Hex	No	NA	NA	NA	1.83 ± 0.70mm	Single crowns, two & three-unit FPDs	Cement	Standardized PA	Yes Significant CBL can be avoided if tissue thickness was ≥ 2.5mm	Yes	No
	Subcrestal implant placement																					
	Al Amri et al. (2016)	2016	Saudi Arabia	23	SM-RCT	Straumann; Bone level RC	Bone level	-2mm	SLA(Sand blasted Large grit Acid etched)	Rough surface	Morse taper	Yes	4.1mm	10 & 12mm	No	0.3 ± 0.2mm	Single crowns	Screw	Standardized PA	No	No	Yes
	Pellicer-Chover et al. (2016)	2016	Spain	13	PCC	Mozo-Grau; Inhex	Bone level	-2mm	Reabsorbable Blast Media	Rough surface with micro threads	Morse taper	Yes	3.7, 4.2 & 5.0mm	10, 11.5 & 12mm	No	1.22 ± 1.06mm	Single crowns	Screw	Standardized PA	No	No	No
	Gualini (2017)	2017	Italy	59	SM-RCT	Anthogyr; Axiom	Bone level	-0.5mm	SA, BCP coated	Rough surface	Morse taper	Yes	3.4, 4, 4.6 & 5.4mm	8, 10, 12 & 13mm	Yes	0.21 ± 0.51mm	Single crowns	Cement	Standardized PA	No	No	Yes
	Gualini (2017)	2017	Italy	57	SM-RCT	Anthogyr; Axiom	Bone level	-1.5mm	SA, BCP coated	Rough surface	Morse taper	Yes	3.4, 4, 4.6 & 5.5mm	8, 10, 12 & 14mm	Yes	0.11 ± 0.36mm	Single crowns	Cement	Standardized PA	No	No	Yes
	Veis et al. (2010)	2010	Greece	64	PCC	Biomet 3i; Full osseotite	Bone level	-1 to -2mm	Dual Acid etched	Rough surface	Internal Hex	No	5mm	NA	NA	0.81 ± 0.79mm	NA	NA	Standardized PA	No	No	No
	Veis et al. (2010)	2010	Greece	25	PCC	Biomet 3i; Full osseotite	Bone level	-1 to -2mm	Dual Acid etched	Rough surface	Internal Hex	Yes	5mm	NA	NA	0.39 ± 0.52mm	NA	NA	Standardized PA	No	No	No
	Kütan et al. (2015)	2015	Turkey	28	SM-RCT	Astra Tech; Osseospeed	Bone level	-1mm	TiO blasted flouride treated	Rough surface with micro threads	Morse taper	Yes	3.5 & 4mm	10 & 13mm	No	1.21 ± 1.05mm	Single crown, splinted crowns & FPDs	Cement	Standardized PA	No	No	No
	Koutouzis et al. (2014)	2014	USA	10	RCT	Dentsply; Ankylos CX	Bone level (subcrestal optional)	-1mm	Acid etched sand blasted	Acid etched sand blasted	Morse taper	Yes	NA	NA	No	0.65 ± 0.45mm	Single crowns	Screw	CBCT	No	Yes No statistically significant correlations between buccal mucosa thickness and CBL.	No
	Koutouzis et al. (2014)	2014	USA	10	RCT	Dentsply; Ankylos CX	Bone level (subcrestal optional)	-2mm	Acid etched sand blasted	Acid etched sand blasted	Morse taper	Yes	NA	NA	No	0.85 ± 0.75mm	Single crowns	Screw	CBCT	No		
	De Siqueira et al. (2016)	2016	Brazil	27	RCT	Neodent; Titamax CX	Bone level	-2mm	Acid etched sand blasted	Acid etched sand blasted	Morse taper	Yes	NA	NA	NA	0.66 ± 0.38mm	Hybrid Prosthesis	Screw	Standardized PA	Yes Soft tissue recession is not significantly influenced by vertical tissue thickness. Correlation between CBL & peri-implant tissue thickness was not assessed.	Yes	Yes
	Supracrestal implant placement																					
	Veis et al. (2010)	2010	Greece	64	PCC	Biomet 3i; Full osseotite	Bone level	+1 to +2mm	Dual Acid etched	Rough surface	Internal Hex	No	5mm	NA	NA	0.60 ± 0.67mm	NA	NA	Standardized PA	No	No	No

	Veis et al. (2010)	2010	Greece	34	PCC	Biomet 3i; Full osseotite	Bone level	+1 to +2mm	Dual Acid etched	Rough surface	Internal Hex	Yes	5mm	NA	NA	0.69 ± 0.47mm	NA	NA	Standardized PA	No	No	No
	Linkevicius et al. (2009)	2009	Lithuania	23	PCC	BioHorizons; Prodigy	Bone level (supracrestal optional)	+2mm	Resorbable Blast Textured	Rough laser-lok surface (1.5mm)	Internal Hex	No	NA	NA	NA	0.81 ± 0.88mm	Single crowns, two-unit & three-unit FPDs	Cement	Standardized PA	Yes Significant CBL can be avoided if tissue thickness was ≥ 2.5mm	Yes	No
	Equicrestal implant placement																				
	Fernndez-Formoso et al.(2012)	2012	Spain	56	RCT	Straumann; Standard plus	Soft tissue level	+1.8mm	SLA(Sand blasted Large grit Acid etched)	1.8mm polished collar	Intenal octagon with short cone	No	3.3, 4.1 & 4.8mm	8 & 12mm	No	2.23 ± 0 22mm	Single non-splinted rowns	Cement	Standardized PA	No	No	No
	Hämmele et al. (1996)	1996	Switzerland	14	PCC	ITI; Hollow screw & hollow cylinder	Soft tissue level	+3mm	TPS (Titanium Plasma Spray)	2.8mm polished collar	Internal with short cone	No	NA	NA	NA	1.02 ± 0.78mm	Single crowns and conventional FPDs	Cement	Standardized PA	No	No	No
	Hartman & Cochran (2004)	2004	USA	46	PC	ITI; Hollow screw & hollow cylinder	Soft tissue level	+2.8mm	TPS (Titanium Plasma Spray)	2.8mm polished collar	Internal with short cone	No	NA	NA	NA	0.68 ± 0.12mm	NA	NA	Standardized PA	No	No	No
	Subcrestal implant placement																				
	Hämmele et al. (1996)	1996	Switzerland	14	PCC	ITI; Hollow screw & hollow cylinder	Soft tissue level	+2mm	TPS (Titanium Plasma Spray)	2.8mm polished collar	Internal with short cone	No	NA	NA	NA	2.26 ± 0.63mm	Single crowns and conventional FPDs	Cement	Standardized PA	No	No	No
	Hartman & Cochran (2004)	2004	USA	68	PC	ITI; Solid screw & hollow cylinder	Soft tissue level	+1.29mm	TPS (Titanium Plasma Spray)	2.8mm polished collar	Internal with short cone	No	NA	NA	NA	1.72 ± 0.15mm	NA	NA	Standardized PA	No	No	No

Table 3: Results by main groups

	Bone level implants	Tissue level implants
Supracrestal before abutment connection	0.03±0.30mm	N/A
Supracrestal after abutment connection	0.66±0.11mm	N/A
Equicrestal before abutment connection	0.57±0.29mm	0.68±0.12mm*
Equicrestal after abutment connection	0.80±0.30mm	0.69±0.54mm
Subcrestal before abutment connection	0.52±0.14mm	1.72±0.15mm
Subcrestal after abutment connection	0.57±0.19mm	2.26±0.63mm