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Review Article

What is the effect of soft tissue thickness on crestal bone loss around dental implants? A systematic review

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Key words: Alveolar bone loss, biotype, dental implant, soft tissue thickness

Abstract

Objectives: The aim of this systematic review was to determine whether soft tissue biotype at implant placement has an influence on crestal bone loss (CBL) at 1 year after implant loading.

Material and methods: Following electronic search in three databases (MEDLINE via OVID, EMBASE and The Cochrane Database) and hand search up to April 2015, two reviewers screened independently and in duplicate the references to identify randomized controlled trials, controlled clinical trials (CCTs) and prospective case series eligible for systematic review and meta-analysis. Cochrane Collaboration's tool was used for assessing risk of bias.

Results: From 2944 citations, six studies (6 CCTs) met the inclusion criteria. Four of six individual studies that compared thin vs. thick biotype showed significantly higher CBL in thin biotype. Meta-analysis could only be performed with two studies and the differences did not reach significant level. None of the included studies was of low risk of bias.

Conclusions: At present, there is insufficient evidence to answer the question on the differences in clinical outcome in terms of CBL between implants placed in sites with initial soft tissue thickness <2 mm and those with ≥2 mm. Further, well-designed controlled clinical studies are needed to analyze the effect of soft tissue thickness on the clinical outcomes of dental implants.

The maintenance of healthy peri-implant tissues is essential for the longevity of dental implants (Renvert & Quirynen 2015). Changes in peri-implant hard and soft tissues as well as restorative and patient-based subjective measures are the most widely used parameters for evaluating the outcomes of implant therapy (Papaspyridakos et al. 2012). Marginal bone levels are expected to become stable by the first year of functional loading, and, after this, an annual crestal bone loss (CBL) of more than 0.2 mm is regarded as undesirable (Albrektsson et al. 1986; Misch et al. 2008). However, 1.5–2 mm CBL in the first year might be an acceptable outcome according to several studies as it may be considered a physiological process (Tarnow et al. 2000; Roos-Jansaker et al. 2006; Papaspyridakos et al. 2012).

Crestal bone loss can be physiological or pathological in nature (Tatarakis et al. 2012) and may be influenced by multiple factors (Albrektsson et al. 2012a,b). Some variables that might affect CBL are surgical trauma (Qian et al. 2012), implant positioning (van Eekeren et al. 2015), implant design (Canullo et al. 2010), implant diameter (Petrie & Williams 2005), abutment height (Galindo-Moreno et al. 2015), implant–abutment connection type (Schwarz et al. 2014), prosthetic design (Cardaropoli et al. 2006), the presence of pathogenic microflora (Lindhe & Meyle 2008) and smoking (Galindo-Moreno et al. 2005).

The results of a recent preclinical study reported that a thin mucosa at the time of implant installation resulted in the establishment of a "biologic width" related CBL during wound healing (Baffone et al. 2013). In natural teeth, the average biologic width (from the base of the sulcus to the alveolar bone margin) was found to be 2.04 mm, of which 0.97 mm was epithelial attachment and 1.07 mm was connective tissue attachment (Gargiulo et al. 1961). In implants, it was first described as the dimension between the first bone-to-implant contact and the apical extension of the junctional epithelium around non-submerged, one-piece dental implants (Cochran et al. 1997). Transmucosal attachment surrounding

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implants seems to be established either at the time of wound healing following implant placement or at abutment connection (Lindhe et al. 2015); the mechanism involves epithelial proliferation followed by collagen fiber organization and may take several weeks to be completed (Berglundh et al. 2007; Hämmerle & Giannobile 2014). This attachment is called "biologic width" and serves as a seal responsible for the protection of peri-implant hard tissues (Cochran et al. 1997; Berglundh et al. 2007). The maintenance of a healthy and unviolated biologic width around implants is crucial for long-term success (Berglundh et al. 1991; Hermann et al. 2000). However, there is controversy in the literature about the height of peri-implant mucosa that could be considered as adequate to form biologic width around implants.

Peri-implant soft tissue thickness, or soft tissue biotype, is mostly referred to as thin or thick, even though it has been reported that a majority of soft tissues might be of mixed pattern (Müller et al. 2000; Müller & Könönen 2005) with individual variations (Kan et al. 2003).

The aim of this systematic review and meta-analysis is to investigate the relation between peri-implant soft tissue thickness and CBL.

Material and methods

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Moher et al. 2009) was followed.

Focused question

The question addressed was the following: "What are the differences in clinical outcome in terms of CBL between implants placed in sites with initial soft tissue thickness <2 mm and those with ≥2 mm?"

Types of studies

Prospective clinical studies assessing CBL around implants placed in subjects with thin or thick biotype were considered. Only studies with at least ten patients per group were selected, to exclude individual case reports.

Populations of studies

Systemically healthy subjects who received dental implants a minimum of 4 months after tooth extraction were included.

Intervention

Following an initial baseline evaluation of mucosal tissue biotype, patients were divided into thin biotype group (<2 mm; test group) and thick biotype group (≥2 mm; control group).

Patients received dental implants with late implantation, standard loading protocol and fixed restorations. No restriction related to the flap technique (flap/flapless), implant design (internal/external/conical) and surgical stage (one/two stage) was initially applied to avoid omitting relevant data. However, soft tissue augmentation for increasing soft tissue thickness was an exclusion criterion.

Comparison

The differences in clinical outcome in terms of radiographic CBL between implants placed in sites with thin biotype (<2 mm) and thick biotype (≥2 mm) were analyzed.

Outcome

The primary outcome of this review was the radiographic CBL 12-month after implant loading. Secondary outcomes considered were the changes in vestibular soft tissue dimension and in papillary height as well as implant survival and/or success rates.

Search methods for identification of studies

A sensitive strategy has been developed aiming to identify all observational studies reporting on relations between soft tissue biotype and CBL. The search strategy included terms related to the population and the intervention investigated in this review and was performed in three databases, MEDLINE via OVID, EMBASE and The Cochrane Database (including the Central Register of Controlled Trials [CENTER]), updated to April 2015.

For the electronic search in MEDLINE and EMBASE, MeSH terms and free-text words were combined as follows (Table 1):

Population: Dental Implants OR implant* AND (soft$ OR mucos$) adj5 tissue$ AND biotype* AND biolog* adj5 width.

Intervention/Exposure: Alveolar Bone Loss $ AND Mouth mucosa (crest$ OR margin$ OR radiograph$) OR alveolar AND (bone$ OR "hard tissue"$) AND alveol$ bone$ loss.

The results were limited to human studies.

Moreover, references of review articles on this topic and of all studies included for data extraction were screened. In the attempt to include also unpublished data, a specific theses database, www.theses.com, was additionally screened. Finally, gray literature was searched in opensigle.inist.fr. The following journals were hand-searched for this review: British Journal of Oral and Maxillofacial Surgery, Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, European Journal of Oral Implantology, Implant Dentistry, International Journal of Oral and Maxillofacial Implants, International Journal of Oral and Maxillofacial Surgery, International Journal of Periodontics and Restorative Dentistry, International Journal of Prosthodontics, Journal of Clinical Periodontology, Journal of Dental Research, Journal of Oral Implantology, Journal of Esthetic and Restorative Dentistry, Journal of Oral and Maxillofacial Surgery, Journal of Periodontology and Journal of Prosthetic Dentistry. No language restrictions were applied.

Screening methods

All three-stage screening (titles, abstract and full text) were carried out in duplicate and independently by two reviewers (AA and CS). Irrelevant records were excluded in these stages (Fig. 1). Full text of possibly eligible

Table 1. **Search strategy for MEDLINE and EMBASE**

MEDLINE via OVID (For Ovid OLD MEDLINE 1946 to 1965, Ovid MEDLINE In process & other non-indexed citations and Ovid MEDLINE 1946 to April 2015)			
	MeSH terms	Free-text search	Limits
Population	exp Dental Implants	OR implant* AND (soft$ OR mucos$) adj5 tissue$ AND biotype* AND biolog* adj5 width	NOT (animals NOT humans)
Intervention/ Exposure	exp Alveolar Bone Loss$ AND Mouth mucosa	(crest$ OR margin$ OR radiograph$) OR alveolar AND (bone$ OR "hard tissue"$) AND alveol$ bone$ loss	
EMBASE (from 1980 to April 2015) and EMBASE Classic (from 1947 to 1979)			
	Emtree terms	Free-text search	Limits
Population	exp Tooth Implant exp Biotype	OR implant* AND (soft$ OR mucos$) adj5 tissue$ AND biotype* AND biolog* adj5 width	NOT (animals NOT humans)
Intervention/ Exposure	exp Alveolar Bone Loss$ AND Mouth mucosa	(crest$ OR margin$ OR radiograph$) OR alveolar AND (bone$ OR "hard tissue"$) AND alveol$ bone$ loss AND	

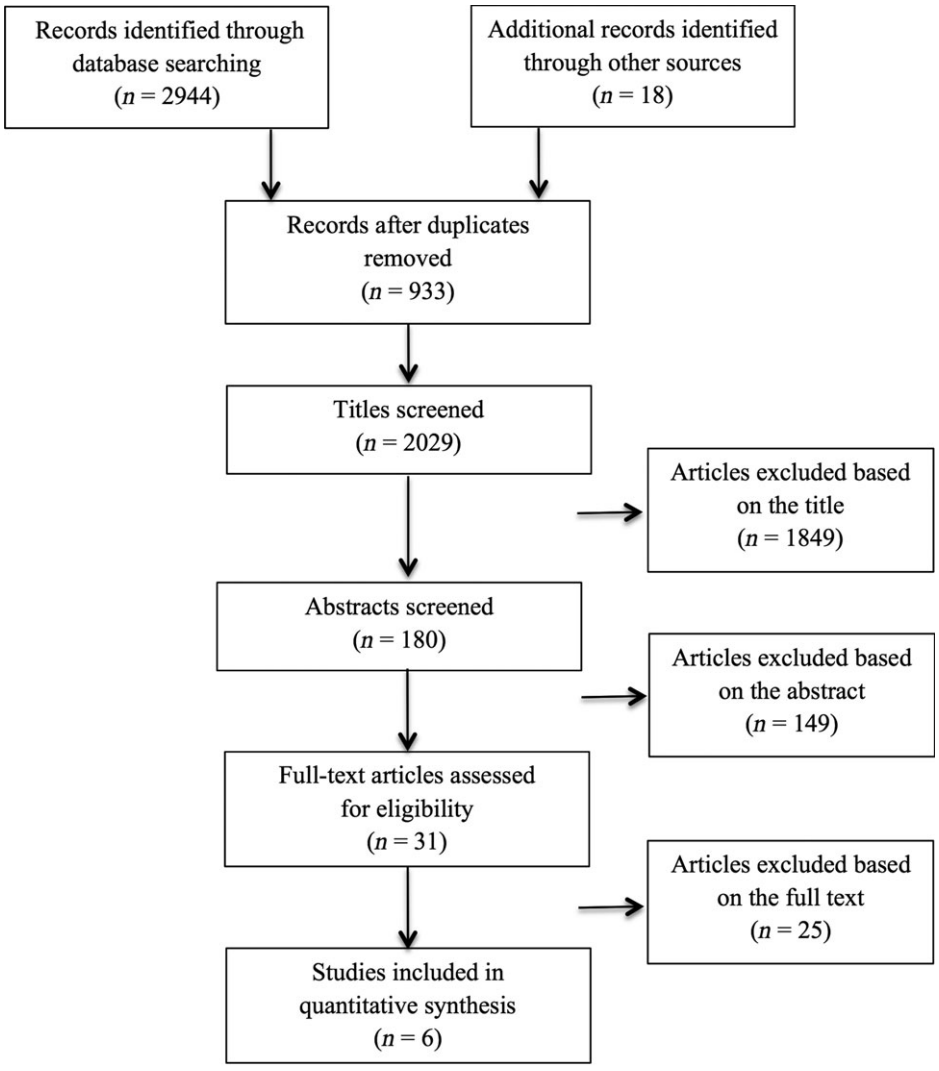

Fig. 1. Four-phase flow diagram of the article selection procedure, according to PRISMA statement (Moher et al. 2009).

studies was reviewed, and any disagreement was resolved by discussion and, if necessary, a third reviewer (ATE) was consulted.

Data extraction

At the stage of full-text screening, a data extraction form was completed to check eligibility of the studies and, if eligible, to collect detailed information about population, intervention and outcomes. For each selected study, the following data were extracted: details of study and population characteristics, methodology and statistics, intervention characteristics and outcomes. If any data were missing or incomplete, the authors were contacted via email allowing a period of 4 weeks to reply. Author responses and reasons for study exclusion were recorded (Table 2).

Quality assessment

The risk of bias assessment of the included trials was assessed independently and in duplicate by at least two review authors (AA, CS, ATE) as part of the data extraction process. This was conducted using the Cochrane Collaboration's tool for assessing risk of bias (Higgins & Green 2011). This is a two-part tool, addressing the six specific domains (namely sequence generation, allocation concealment, blind outcome assessment, incomplete outcome data, selective outcome reporting and "other issues") and each domain includes one specific entry in a "risk of bias" table. Within each entry, the first part of the tool involves describing what was reported to have happened in the study. The second part of the tool involves assigning a judgment relating to the risk of bias for that entry, defined as low, unclear or high. Sequence generation, was not assessed as controlled clinical studies were to be included; allocation concealment was not evaluated as biotype cannot be hidden from the surgeon. Graphics were obtained with Review Manager 5.3 (Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark).

Statistical analysis

Meta-analysis was carried out for both continuous and dichotomous measures with the statistical software MedCalc 15.8 (MedCalc Software bvba, Ostend, Belgium). The statistical unit was the patient.

Under the fixed-effects model, it is assumed that all studies come from a common population and that the effect size (standardized mean difference equal to the difference in means divided by the pooled standard deviation) is similar among the different trials. This assumption was tested by the "heterogeneity test" and by consideration of the I^2 statistic, which represents the percentage of the total variation across studies due to heterogeneity. Due to a significant heterogeneity between the studies, a random-effects model was more appropriate, in which both the random variation within the studies and the variation between the different studies are incorporated.

The level of agreement between the two reviewers regarding relevant factors in the studies were determined using kappa statistics.

Results

Studies included

The initial search resulted in 2962 articles (1298 articles at MEDLINE via OVİD, 1607 at EMBASE, 39 articles at Cochrane Database and 18 articles at additional sources). After checking for duplicated articles, 933 articles were excluded, resulting in 2029 potentially eligible articles. Following title screening, 180 articles were selected for abstract screening, and of these, 31 full-text articles were assessed for eligibility. Six (6) articles met the defined inclusion criteria, and 25 papers were excluded (Fig. 1). The reasons for exclusion of the studies at the level of full-text screening are reported in Table 2.

Kappa statistics showed a high level of agreement between the reviewers ($K > 0.90$). All the included studies had a controlled clinical trial design; two studies were split mouth (Linkevicius et al. 2009a; Linkevicius et al. 2015c) and four were parallel design (Kaminaka et al. 2014; Linkevicius et al. 2015a,b; Puisys & Linkevicius 2015) (Table 3).

Study characteristics

Studies included a minimum of 19 (Linkevicius et al. 2009a) up to 103 patients (Linkevicius et al. 2015a) with ages ranging from 19

Table 2. **Reasons for exclusions of the 25 studies at the level of full-text screening**

Author and year	Reasons for exclusion
Aguirre-Zorzano et al. (2013)*	Retrospective design, immediate implant placement and over denture is included in study population
Bashutski et al. (2013)*	Study population not classified according to biotype
Becker et al. (2005)	Baseline soft tissue thickness is not assessed
Buchs et al. (1996)	Baseline soft tissue thickness is not assessed
Canullo et al. (2012)	Baseline soft tissue thickness is not assessed
Cardaropoli et al. (2006)	Study population not classified according to biotype
Fernandes (2011)	Baseline soft tissue thickness is not assessed and no information about implant placement or loading protocol
Gallucci et al. (2011)*	Baseline soft tissue thickness is not assessed
Jeong et al. (2011)	Radiographic crestal bone loss assessment is reported 12 months after the implant placement not restoration
Kan et al. (2003)	No information about the implant placement protocol and radiographic crestal bone loss is not reported
Kehl et al. (2011)	Loading protocol is not reported and baseline soft tissue thickness is not assessed
Linkevicius et al. (2009b)	Insufficient number of patients
Linkevicius et al. (2010)	Insufficient number of patients
Nisapakultorn et al. (2010)	No information about implant placement or loading protocol
Puisys et al. (2015)	No information about implant placement, loading protocol or type of restoration
Rasner (2013)	Insufficient number of patients
Sanz Martin et al. (2016)	Patients received guided bone regenerative procedures and removable prostheses are included in study population
Takuma et al. (2014)	Baseline soft tissue thickness is not assessed and radiographic crestal bone loss assessment is reported 12 months after the implant placement not restoration
Tan et al. (2011)*	No information about the thickness of the mucosa per patient and their related mean crestal bone loss 1 year after loading
Torkzaban et al. (2015)*	No information about radiographic crestal bone loss according to biotype
Trammell et al. (2009)	Insufficient number of patients
Vandeweghe & De Bruyn (2012)*	No information about the thickness of the mucosa per patient and their related mean crestal bone loss 1 year after the loading
Vervaeke et al. (2014)	Fully edentulous patients are included and immediate loading
Vervaeke et al. (2016)	Fully edentulous patients are included and immediate loading
Wiesner et al. (2010)	Insufficient number of patients

*Author responses to e-mail contact for any missing or incomplete data.

to 85 years (Kaminaka et al. 2014; Linkevicius et al. 2015b). In all the included trials, the operators were specialists. Five studies reported excluding smokers; the remainder (Linkevicius et al. 2009a) did not report on smoking.

Baseline soft tissue thickness was evaluated using either CBCT (Kaminaka et al. 2014) or a periodontal probe. Study groups were either "augmented" (soft tissue augmentation, which were not included in this review), thin or thick biotype. Bone-level implants were placed after flap elevation in all included studies. Only one study reported performing second-stage surgery (Kaminaka et al. 2014).

Fixed metal–ceramic restorations were constructed either as a single (Linkevicius et al. 2015a,b; Puisys & Linkevicius 2015) or multiple units (Linkevicius et al. 2009a, 2015c; Kaminaka et al. 2014). Only Kaminaka et al. measured the CBL using CBCT (Kaminaka et al. 2014); the other five studies evaluated CBL with periapical radiographs. Success criteria for the implants were defined only in one study (Kaminaka et al. 2014) as there is no clinical sign of peri-implant soft tissue inflammation.

The administration time of the antibiotics varied among the studies. In four studies, patients received antibiotics before the surgery (Linkevicius et al. 2009a, 2015b,c; Puisys & Linkevicius 2015), one postoperatively (Kaminaka et al. 2014) and the remainder prescribed both preoperatively and postoperatively (Linkevicius et al. 2015a).

Study outcomes

Radiographic CBL at 12 months after implant loading was evaluated in all studies (Table 4). Kaminaka et al. 2014 (Kaminaka et al. 2014) compared soft tissue changes around implants with different abutment connection designs and reported CBL as 1.33 ± 1.11 in thin biotype group and 0.31 ± 0.34 in thick biotype group ($P < 0.001$).

In 2009, a study by Linkevicius et al. reported on 10 patients that only in the thick biotype group, the CBL was 0.17 ± 0.19 (Linkevicius et al. 2009a). Linkevicius et al. (2015a) compared thin, thick and augmented biotypes and found that the mean CBL values were 1.65 ± 0.08 and 0.44 ± 0.06 in thin and thick biotypes, respectively ($P < 0.001$) (Linkevicius et al. 2015a). In 2015, Linkevicius et al. (Linkevicius et al. 2015b) evaluated CBL around platform-switched implants placed in thin and thick biotype and found that the mean (min–max) CBL was 1.18 (0.1–2.1) and 0.22 (0–1.1), respectively ($P < 0.001$). In a similar study design, CBL was reported as 1.22 ± 0.08 and 0.22 ± 0.06 ($P < 0.001$) (Puisys & Linkevicius 2015). Another trial included implants placed in only thin biotype and compared different connection designs, finding a CBL of 1.43 ± 0.23 (Linkevicius et al. 2015c).

The four studies that compared thin vs. thick biotype (Kaminaka et al. 2014; Linkevicius et al. 2015a,b; Puisys & Linkevicius 2015) showed significantly higher CBL in thin biotype.

Meta-analysis could only be carried out with two studies (Linkevicius et al. 2015a; Puisys & Linkevicius 2015). One study had to be excluded due to providing only the implant as unit of analysis (Kaminaka et al. 2014) and the other due to not reporting standard deviations (Linkevicius et al. 2015b). No statistically significant differences were found for CBL between thin and thick biotype ($P = 0.189$) using the random-effects model. A fixed-effects model was not considered statistically appropriate due to the high heterogeneity between the studies.

Regarding changes in vestibular soft tissue dimension, a mean loss in soft tissue height (measured from the implant platform to the marginal soft tissue level) of 0.31 ± 0.27 in the thin biotype group and 0.08 ± 0.06 in the thick biotype group ($P < 0.001$) was reported (Kaminaka et al. 2014).

None of the studies reported changes in papillary height.

All studies reported a success and survival rate of 100% (Linkevicius et al. 2009a, 2015a, b,c; Kaminaka et al. 2014; Puisys & Linkevicius 2015)

Risk of bias assessment of the included trials is summarized in Figs 2 and 3. None of the included studies were at low risk of bias.

Discussion

The classification of the soft tissue thickness shows high variation among different studies. Thin biotype has been described as ≤1.5 and <1.5 mm, respectively (Claffey & Shanley 1986 and Bashutski & Wang 2007), or <1 to

Table 3. **Study characteristics of included studies**

Study, year	Country, type of center / number	Funding	Study type / design	Experience / number of operators	Subjects / Implants	Mean age ± SD and/or range	Smokers included
Kaminaka et al. 2014	Japan, University/1	Self-funded	CCT/Parallel	Specialist/Unclear	32/34	28–85	N
Linkevicius et al. 2009a	Lithuania, Private/1	Unclear	CCT/Split mouth	Specialist/Single	19/23	23–71	Unclear
Linkevicius et al. 2015a	Lithuania, Private/1	Unclear	CCT/Parallel	Specialist/Single	103/103	45.3 ± 1.2 and 21–55	N
Linkevicius et al. 2015b	Lithuania, Private/1	Unclear	CCT/Parallel	Specialist/Single	80/80	44 ± 3.34 and 19–52	N
Linkevicius et al. 2015c	Lithuania, Private/1	Unclear	CCT/Split mouth	Specialist/Unclear	30/60	42.3 ± 2.4 and 20–55	N
Puisys & Linkevicius 2015	Lithuania, Private/1	Unclear	CCT/Parallel	Specialist/Unclear	97/97	47.3 ± 1.2; 21–65	N

Study, year	How soft tissue measured	Intervention group (Biotype)	Implant type / stages / flapless (Y/N)	Restoration type (single / bridge / combination)	Antibiotics administration (Preoperative and/or postoperative)	How crestal bone loss measured	Implant follow-up after implant loading	Success criteria
Kaminaka et al. 2014	CBCT	Thin / Thick	Bone level, Brånemark System, NobelSpeedy Groovy; NobelReplace, NobelSpeedy Replace; NobelActive /2/N	Combination	Postoperative	CBCT	1 year	Self-defined criteria
Linkevicius et al. 2009a	Periodontal probe	Thin / Thick	Bone level, Prodigy, Biohorizons/1/N	Combination	Preoperative	Periapical radiographs	1 year	–
Linkevicius et al. 2015a	Periodontal probe	Thin / Thick / Augmented	Bone level, BioHorizons/1/N	Single	Preoperative and postoperative	Periapical radiographs	1 year	–
Linkevicius et al. 2015b	Periodontal probe	Thin / Thick	Bone level, Straumann/1/N	Single	Preoperative	Periapical radiographs	1 year	–
Linkevicius et al. 2015c	Periodontal probe	Thin	Bone level, Biomet Tapered Internal Laser Lock; Certain prevail, Biomet/3i / 1/N	Combination	Preoperative	Periapical radiographs	1 year	–
Puisys & Linkevicius 2015	Periodontal probe	Thin / Thick / Augmented	Bone level, Straumann/1/N	Single	Preoperative	Periapical radiographs	1 year	–

Table 4. **Study outcomes of included papers**

Study, year	Comparison	Radiographic crestal bone loss (mm) (Mean ± SD or Mean (min–max))	Changes in vestibular soft tissue dimension	Changes in papillary height	Success rate (%)	Survival rate (%)
Kaminaka et al. 2014	Thin vs. Thick Biotype	1.33 ± 1.11 vs. 0.31 ± 0.34*	0.31 ± 0.27 vs. 0.08 ± 0.06*	–	–	100% vs. 100%
Linkevicius et al. 2009a	Thick Biotype	0.17 ± 0.19	–	–	100%	–
Linkevicius et al. 2015a	Thin vs. Thick Biotype	1.65 ± 0.08 vs. 0.44 ± 0.06	–	–	–	100% vs. 100%
Linkevicius et al. 2015b	Thin vs. Thick Biotype	1.18 (0.1–2.1) vs. 0.22 (0–1.1)	–	–	–	100% vs. 100%
Linkevicius et al. 2015c	Thin Biotype	1.43 ± 0.23	–	–	–	100%
Puisys & Linkevicius 2015	Thin vs. Thick Biotype	1.22 ± 0.08 vs. 0.22 ± 0.06	–	–	–	100% vs. 100%

*Data obtained through author contact.

2 mm (Chen et al. 2009), whereas thick biotype has been defined as from >1 to 2 mm (Chen et al. 2009), ≥1.5 mm (Bashutski & Wang 2007) or ≥2 mm (Claffey & Shanley 1986). In a recent systematic review (Suárez-López Del Amo et al. 2016) and the present systematic review, thin biotype was described as <2 mm and thick as ≥2 mm. Different diagnostic methods have been used to measure soft tissue, which may in turn influence the definition of the biotype (thick or thin). Some examples of biotype assessment methods are visual recognition of the outline of the probe through the marginal tissue (Kan et al. 2003), a method based on an assessment of a ratio between the crown length and width (Olsson & Lindhe 1991), ultrasonic instruments (Müller et al. 2000), direct measurement with calipers or trans-gingival sounding (Frost et al. 2015). The included studies measured baseline soft tissue thickness with either CBCT or periodontal probe prior to implant placement. Although soft tissue thickness can be measured by periodontal probe in a simple way, the measurement results in accuracy to the nearest 0.5 mm. CBCT offers a high accuracy in assessing soft tissue thickness but requires an exposure to radiation, which may not be justifiable (Zweers et al. 2014).

It has been suggested that the initial amount of soft tissue thickness may have a crucial role in the outcome of dental implant treatment (Hermann et al. 2000; Lee et al. 2011; Baffone et al. 2013; Thoma et al. 2014). In a preclinical study, it was observed that, when the thickness of the mucosa was reduced experimentally, bone resorption took place to create biologic width (Berglundh & Lindhe 1996). Also, an experimental study in dogs showed that increased thickness of the soft tissue reduced CBL (Bengazi et al. 2015).

Furthermore, it was reported that early bone remodeling was influenced by the initial soft tissue thickness in edentulous patients with two non-splinted implants supporting an overdenture (Vervaeke et al. 2014).

According to the results of a recent meta-analysis (Suárez-López Del Amo et al. 2016), the weighted mean difference between thick and thin biotype was reported as −0.80 mm (95% CI = −1.18 mm to −0.42 mm) with significantly less CBL in the thick group, when the implant was considered as the unit of analysis. The present systematic review was designed with the patient as the unit of analysis, and baseline was the time of implant loading rather than implant placement. Moreover, author responses for the missing or unpublished data were included in the current review. These differences could explain the different conclusions reached despite a similar focused question.

The primary outcome of the present systematic review was the evaluation of the radiographic CBL. Even though the periapical radiographs have been reported as an ideal method for peri-implant CBL measurement (Albrektsson et al. 2012a,b), three-dimensional radiographic measurements could provide additional relevant information. However, only one of the six included studies used CBCT.

The type of implant and its supra- or subcrestal placement, surgical technique (flap/flapless), type of restoration and smoking have been considered as important confounding factors on CBL (Tatarakis et al. 2012). The implant types included in the present systematic review were bone level, and as long as they were placed in accordance with the manufacturer's recommendations, implant placement depth would not have differed significantly between the included studies. Other factors such as distance between implant and adjacent teeth, or location of the implants within the jaw (adjacent to teeth or edentulous space), might have had an effect on CBL.

Although the importance of the peri-implant mucosal thickness has been further emphasized, the adequate thickness (in millimeters) to preserve CBL still remains controversial.

In its intention to analyze the differences in clinical outcome between thin and thick soft tissue biotypes, this review identified only four clinical trials that directly compared CBL after delayed implant placement and standard loading protocol with fixed prostheses in these two groups with a follow-up of at least 12 months after loading. All of the studies were at unclear or high risk of bias, which weakens confidence in the results (Higgins & Green 2011). A recent systematic review also reported potential bias of the selected studies (Suárez-López Del Amo et al. 2016). Despite the fact that the four studies independently reported significant differences, the meta-analysis did not find statistically significant differences, most likely due to the heterogeneity between the studies. The included studies reported a 100% survival rate in both groups.

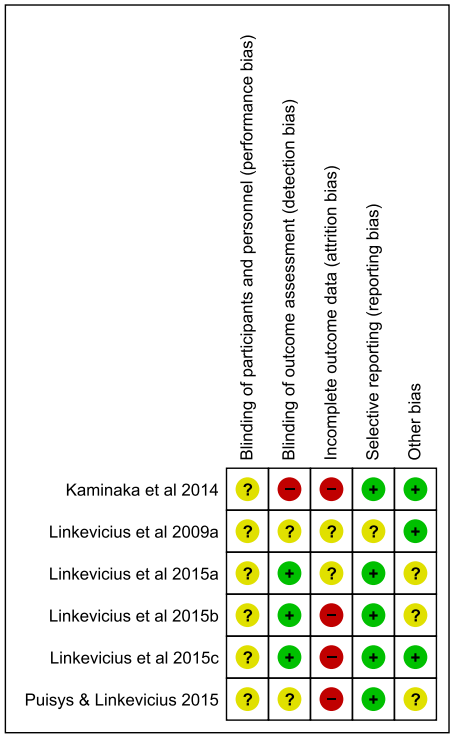

Fig. 2. Risk of bias summary.

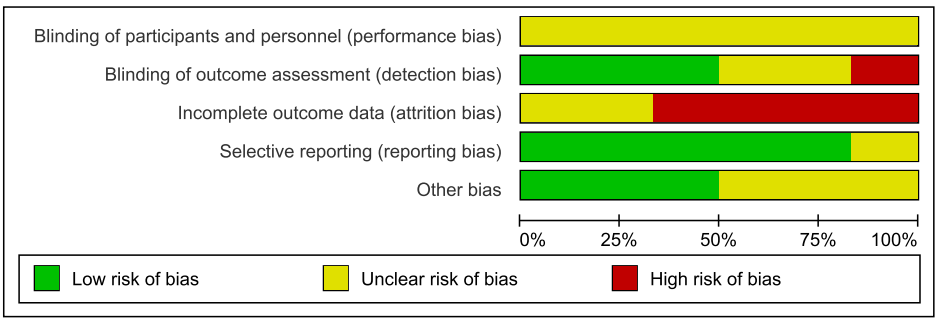

Fig. 3. Risk of bias graph.

Conclusions

At present, there is insufficient amount of evidence to answer the question on the differences in clinical outcome in terms of CBL between implants placed in sites with initial soft tissue thickness <2 mm and those with ≥2 mm. Well-designed controlled clinical trials with low risk of bias are needed to analyze the effect of soft tissue thickness on the clinical outcomes of dental implants. Although it may not be possible to blind the clinicians, blinding of outcome assessors is suggested for future research. Furthermore, decreased heterogeneity and control of all the present source of bias are recommended. There is also a need to find a more reliable, objective and reproducible method to measure soft tissue thickness. Moreover, an understanding of the peri-implant mucosa in a dimensional manner and its possible variations may guide clinicians to predict critical physiological requirements and esthetic demands of the restoration.

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Conflict of interest

All authors declared that they have no conflict of interest in relation to this manuscript.

References

Albrektsson, T., Buser, D. & Sennerby, L. (2012a) On crestal/marginal bone loss around dental implants. *International Journal of Prosthodontics* **25**: 320–322.

Albrektsson, T., Buser, D. & Sennerby, L. (2012b) On crestal/marginal bone loss around dental implants. *International Journal of Oral and Maxillofacial Implants* **27**: 736–738.

Albrektsson, T., Zarb, G., Worthington, P. & Eriksson, A.R. (1986) The long-term efficacy of

currently used dental implants: a review and proposed criteria of success. *International Journal of Oral and Maxillofacial Implants* **1**: 11–25.

Baffone, G.M., Botticelli, D., Pereira, F.P., Favero, G., Schweikert, M. & Lang, N.P. (2013) Influence of buccal bony crest width on marginal dimensions of peri-implant hard and soft tissues after implant installation. An experimental study in dogs. *Clinical Oral Implants Research* **24**: 250–254.

Bashutski, J.D. & Wang, H.L. (2007) Common implant esthetic complications. *Implant Dentistry* **16**: 340–348.

Bengazi, F., Lang, N.P., Caroprese, M., Urbizo Velez, J., Favero, V. & Botticelli, D. (2015) Dimensional changes in soft tissues around dental implants following free gingival grafting: an experimental study in dogs. *Clinical Oral Implants Research* **26**: 176–182.

Berglundh, T., Abrahamsson, I., Welander, M., Lang, N.P. & Lindhe, J. (2007) Morphogenesis of the peri-implant mucosa: an experimental study in dogs. *Clinical Oral Implants Research* **18**: 1–8.

Berglundh, T., Lindhe, J., Ericsson, I., Marinello, C.P., Liljenberg, B. & Thomsen, P. (1991) The soft tissue barrier at implants and teeth. *Clinical Oral Implants Research* **2**: 81–90.

Berglundh, T. & Lindhe, J. (1996) Dimension of the periimplant mucosa. biological width revisited. *Journal of Clinical Periodontology* **23**: 971–973.

Canullo, L., Fedele, G.R., Iannello, G. & Jepsen, S. (2010) Platform switching and marginal bone level alterations: the results of a randomized controlled trial. *Clinical Oral Implants Research* **21**: 115–121.

Cardaropoli, G., Lekholm, U. & Wennstrom, J.L. (2006) Tissue alterations at implant-supported single-tooth replacements: a 1-year prospective clinical study. *Clinical Oral Implants Research* **17**: 165–171.

Chen, S.T., Darby, I.B., Reynolds, E.C. & Clement, J.G. (2009) Immediate implant placement postextraction without flap elevation. *Journal of Periodontology* **80**: 163–172.

Claffey, N. & Shanley, D. (1986) Relationship of gingival thickness and bleeding to loss of probing attachment in shallow sites following nonsurgical periodontal therapy. *Journal of Clinical Periodontology* **13**: 654–657.

Cochran, D.L., Hermann, J.S., Schenk, R.K., Higginbottom, F.L. & Buser, D. (1997) Biologic width around titanium implants. A histometric analysis of the implanto-gingival junction around unloaded and loaded nonsubmerged implants in the canine mandible. *Journal of Periodontology* **68**: 186–198.

Frost, N.A., Mealey, B.L., Jones, A.A. & Huynh-Ba, G. (2015) Periodontal biotype: Gingival thickness as it relates to probe visibility and buccal bone thickness. *Journal of Periodontology* **86**: 1141–1149.

Galindo-Moreno, P., Fauri, M., Avila-Ortiz, G., Fernandez-Barbero, J.E., Cabrera-Leon, A. & Sanchez-Fernandez, E. (2005) Influence of alcohol and tobacco habits on peri-implant marginal bone loss: a prospective study. *Clinical Oral Implants Research* **16**: 579–586.

Galindo-Moreno, P., León-Cano, A., Ortega-Oller, I., Monje, A.O., Valle, F. & Catena, A. (2015) Marginal bone loss as success criterion in implant dentistry: beyond 2 mm. *Clinical Oral Implants Research* **26**: 28–34.

Gargiulo, A.W., Wentz, F.M. & Orban, B. (1961) Dimensions and relations of the dentogingival junction in humans. *Journal of Periodontology* **32**: 261–267.

Hämmerle, C.H. & Giannobile, W.V. (2014) Working Group 1 of the European Workshop on Periodontology. Biology of soft tissue wound healing and regeneration–consensus report of Group 1 of the 10th European Workshop on Periodontology. *Journal of Clinical Periodontology* **41**: 1–5.

Hermann, J.S., Buser, D., Schenk, R.K., Higginbottom, F.L. & Cochran, D.L. (2000) Biologic width around titanium implants. A physiologically formed and stable dimension over time. *Clinical Oral Implants Research* **11**: 1–11.

Higgins, J.P.T. & Green, S. (2011) *Cochrane Handbook for Systematic Reviews of Interventions version 5.1.0.* London: The Cochrane Collaboration.

Kaminaka, A., Nakano, T., Ono, S., Kato, T. & Yatani, H. (2014) Cone-beam computed tomography evaluation of horizontal and vertical dimensional changes in buccal peri-implant alveolar bone and soft tissue: a 1-year prospective clinical study. *Clinical Implant Dentistry and Related Research* **17**: 576–585.

Kan, J.Y., Rungcharassaeng, K., Umezu, K. & Kois, J.C. (2003) Dimensions of peri-implant mucosa: an evaluation of maxillary anterior single implants in humans. *Journal of Periodontology* **74**: 557–562.

Lee, A., Fu, J.H. & Wang, H.L. (2011) Soft tissue biotype affects implant success. *Implant Dentistry* **20**: 38–47.

Lindhe, J. & Meyle, J.; Group D of European Workshop on Periodontology(2008) Peri-implant diseases: Consensus Report of the Sixth European Workshop on Periodontology. *Journal of Clinical Periodontology* **35**: 282–285.

Lindhe, J., Wennström, J.L. & Berglundh, T. (2015) The mucosa at teeth and implants. In: Lang, N.P. & Lindhe, J., eds. *Clinical Periodontology and Implant Dentistry, 6th edition*, p. 1020. Oxford: Blackwell Munksgaard.

Linkevicius, T., Apse, P., Grybauskas, S. & Puisys, A. (2009a) The influence of soft tissue thickness on crestal bone changes around implants: a 1-year prospective controlled clinical trial. *International Journal of Oral and Maxillofacial Implants* **24**: 712–719.

Linkevicius, T., Puisys, A., Linkeviciene, L., Peciuliene, V. & Schlee, M. (2015a) Crestal bone stability around implants with horizontally matching connection after soft tissue thickening: a prospective clinical trial. *Clinical Implant Dentistry and Related Research* **17**: 497–508.

Linkevicius, T., Puisys, A., Steigmann, M., Vindasiute, E. & Linkeviciene, L. (2015b) Influence of vertical soft tissue thickness on crestal bone changes around implants with platform switching: a comparative clinical study. *Clinical Implant Dentistry and Related Research* **17**: 1228–1236.

Linkevicius, T., Puisys, A., Svediene, O., Linkevicius, R. & Linkeviciene, L. (2015c) Radiological comparison of laser-microtextured and platform-switched implants in thin mucosal biotype. *Clinical Oral Implants Research* **26**: 599–605.

Misch, C.E., Perel, M.L., Wang, H.L., Sammartino, G., Galindo-Moreno, P., Trisi, P., Steigmann, M., Rebaudi, A., Palti, A., Pikos, M.A., Schwartz-Arad, D., Choukroun, J., Gutierrez-Perez, J.L., Marenzi, G. & Valavanis, D.K. (2008) Implant success, survival, and failure: the international congress of oral implantologists (icoi) pisa consensus conference. *Implant Dentistry* **17**: 5–15.

Moher, D., Liberati, A., Tetzlaff, J. & Altman, D.G. (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Journal of Clinical Epidemiology* **62**: 1006–1012.

Müller, H.P. & Könönen, E. (2005) Variance components of gingival thickness. *Journal of Periodontal Research* **40**: 239–244.

Müller, H.P., Schaller, N., Eger, T. & Heinecke, A. (2000) Thickness of masticatory mucosa. *Journal of Clinical Periodontology* **27**: 431–436.

Olsson, M. & Lindhe, J. (1991) Periodontal characteristics in individuals with varying form of the upper central incisors. *Journal of Clinical Periodontology* **18**: 78–82.

Papaspyridakos, P., Chen, C.J., Singh, M., Weber, H.P. & Gallucci, G.O. (2012) Success criteria in implant dentistry: a systematic review. *Journal of Dental Research* **91**: 242–248.

Petrie, C.S. & Williams, J.L. (2005) Comparative evaluation of implant designs: influence of diameter, length, and taper on strains in the alveolar crest. A three-dimensional finite-element analysis. *Clinical Oral Implants Research* **16**: 486–494.

Puisys, A. & Linkevicius, T. (2015) The influence of mucosal tissue thickening on crestal bone stability around bone-level implants. A prospective controlled clinical trial. *Clinical Oral Implants Research* **26**: 123–129.

Qian, J., Wennerberg, A. & Albrektsson, T. (2012) Reasons for marginal bone loss around oral implants. *Clinical Implant Dentistry and Related Research* **14**: 792–807.

Renvert, S. & Quirynen, M. (2015) Risk indicators for peri-implantitis. A narrative review. *Clinical Oral Implants Research* **11**: 15–44.

Roos-Jansaker, A.M., Lindahl, C., Renvert, H. & Renvert, S. (2006) Nine- to fourteen-year follow up of implant treatment. Part ii: presence of peri-implant lesions. *Journal of Clinical Periodontology* **33**: 290–295.

Schwarz, F., Hegewald, A. & Becker, J. (2014) Impact of implant-abutment connection and positioning of the machined collar/microgap on crestal bone level changes: a systematic review. *Clinical Oral Implants Research* **25**: 417–425.

Suárez-López Del Amo, F., Lin, G.H., Monje, A., Galindo-Moreno, P. & Wang, H.L. (2016) Influence of soft tissue thickness upon peri-implant marginal bone loss: A Systematic review and meta-analysis. *Journal of Periodontology* **87**: 690–699.

Tarnow, D.P., Cho, S.C. & Wallace, S.S. (2000) The effect of inter-implant distance on the height of inter-implant bone crest. *Journal of Periodontology* **71**: 546–549.

Tatarakis, N., Bashutski, J., Wang, H.L. & Oh, T.J. (2012) Early implant bone loss: preventable or inevitable? *Implant Dentistry* **21**: 379–386.

Thoma, D.S., Mühlemann, S. & Jung, R.E. (2014) Critical soft-tissue dimensions with dental implants and treatment concepts. *Periodontology 2000* **66**: 106–118.

van Eekeren, P., Tahmaseb, A. & Wismeijer, D. (2015) Crestal bone changes in macrogeometrically similar implants with the implant-abutment connection at the crestal bone level or 2.5 mm above: a prospective randomized clinical trial. *Clinical Oral Implants Research*. doi: 10.1111/clr.12581.

Vervaeke, S., Dierens, M., Besseler, J. & De Bruyn, H. (2014) The influence of initial soft tissue thickness on peri-implant bone remodeling. *Clinical Implant Dentistry and Related Research* **16**: 238–247.

Zweers, J., Thomas, R.Z., Slot, D.E., Weisgold, A.S. & Van der Weijden, F.G. (2014) Characteristics of periodontal biotype, its dimensions, associations and prevalence: a systematic review. *Journal of Clinical Periodontology* **41**: 958–971.

References of excluded studies

Aguirre-Zorzano, L.A., Vallejo-Aisa, F.J. & Estefanía-Fresco, R. (2013) Supportive periodontal therapy and periodontal biotype as prognostic factors in implants placed in patients with a history of periodontitis. *Medicina Oral, Patologia Oral y Cirugia Bucal* **18**: 786–792.

Bashutski, J.D., Wang, H.L., Rudek, I., Moreno, I., Koticha, T. & Oh, T.J. (2013) Effect of flapless surgery on single-tooth implants in the esthetic zone: a randomized clinical trial. *Journal of Periodontology* **84**: 1747–1754.

Becker, W., Goldstein, M., Becker, B.E. & Sennerby, L. (2005) Minimally invasive flapless implant surgery: a prospective multicenter study. *Clinical Implant Dentistry and Related Research* **7**: 21–27.

Buchs, A.U., Hahn, J. & Vassos, D.M. (1996) Efficacy of threaded hydroxyapatite-coated implants placed in the posterior mandible in support of fixed prostheses. *Implant Dentistry* **5**: 106–110.

Canullo, L., Rosa, J.C., Pinto, V.S., Francischone, C.E. & Götz, W. (2012) Inward-inclined implant platform for the amplified platform-switching concept: 18-month follow-up report of a prospective randomized matched-pair controlled trial. *International Journal of Oral and Maxillofacial Implants* **27**: 927–934.

Fernandes, A. (2011) Bone level dental implant versus gingival crest level implant. *Dentistry Today* **30**: 72–73.

Gallucci, G.O., Grütter, L., Chuang, S.K. & Belser, U.C. (2011) Dimensional changes of peri-implant soft tissue over 2 years with single-implant crowns in the anterior maxilla. *Journal of Clinical Periodontology* **38**: 293–299.

Jeong, S.M., Choi, B.H., Kim, J., Xuan, F., Lee, D.H., Mo, D.Y. & Lee, C.U. (2011) A 1-year prospective clinical study of soft tissue conditions and marginal bone changes around dental implants after flapless implant surgery. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* **111**: 41–46.

Kehl, M., Swierkot, K. & Mengel, R. (2011) Three-dimensional measurement of bone loss at implants in patients with periodontal disease. *Journal of Periodontology* **82**: 689–699.

Linkevicius, T., Apse, P., Grybauskas, S. & Puisys, A. (2009b) Reaction of crestal bone around implants depending on mucosal tissue thickness. A 1-year prospective clinical study. *Stomatologija* **11**: 83–91.

Linkevicius, T., Apse, P., Grybauskas, S. & Puisys, A. (2010) Influence of thin mucosal tissues on crestal bone stability around implants with platform switching: a 1-year pilot study. *Journal of Oral and Maxillofacial Surgery* **68**: 2272–2277.

Nisapakultorn, K., Suphanantachat, S., Silkosessak, O. & Rattanamongkolgul, S. (2010) Factors affecting soft tissue level around anterior maxillary single-tooth implants. *Clinical Oral Implants Research* **21**: 662–670.

Puisys, A., Vindasiute, E., Linkevciene, L. & Linkevicius, T. (2015) The use of acellular dermal matrix membrane for vertical soft tissue augmentation during submerged implant placement: a case series. *Clinical Oral Implants Research* **26**: 465–470.

Rasner, S.L. (2013) Implant therapy in the aesthetic zone: maintaining gingival margins. *Dentistry Today* **32**: 100–104.

Sanz Martin, I., Benic, G.I., Hämmerle, C.H. & Thoma, D.S. (2016) Prospective randomized controlled clinical study comparing two dental implant types: volumetric soft tissue changes at 1 year of loading. *Clinical Oral Implants Research* **27**: 406–411.

Takuma, T., Oishi, K., Manabe, T., Yoneda, S. & Nagata, T. (2014) Buccal bone resorption around posterior implants after surgery: a 1-year prospective study. *International Journal of Oral and Maxillofacial Implants* **29**: 634–641.

Tan, W.C., Lang, N.P., Schmidlin, K., Zwahlen, M. & Pjetursson, B.E. (2011) The effect of different implant neck configurations on soft and hard tissue healing: a randomized-controlled clinical trial. *Clinical Oral Implants Research* **22**: 14–19.

Torkzaban, P., Arabi, S.R., Roshanaei, G., Rostami, M. & Soheilifar, S. (2015) A comparative study of clinical parameters in submerged and non submerged implants. *Journal of Clinical and Diagnostic Research* **9**: 26–29.

Trammell, K., Geurs, N.C., O'Neal, S.J., Liu, P.R., Haigh, S.J., McNeal, S., Kenealy, J.N. & Reddy, M.S. (2009) A prospective, randomized, controlled comparison of platform-switched and matched-abutment implants in short-span partial denture situations. *International Journal of Periodontics and Restorative Dentistry* **29**: 599–605.

Vandeweghe, S. & De Bruyn, H. (2012) A within-implant comparison to evaluate the concept of platform switching: a randomised controlled trial. *European Journal of Oral Implantology* **5**: 253–262.

Vervaeke, S., Collaert, B., Cosyn, J. & De Bruyn, H. (2016) A 9-year prospective case series using multivariate analyses to identify predictors of early and late peri-implant bone loss. *Clinical Implant Dentistry and Related Research* **18**: 30–39.

Wiesner, G., Esposito, M., Worthington, H. & Schlee, M. (2010) Connective tissue grafts for thickening peri-implant tissues at implant placement. One-year results from an explanatory split-mouth randomised controlled clinical trial. *European Journal of Oral Implantology* **3**: 27–35.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. PRISMA 2009 Checklist.