Accepted: 13 December 2017

DOI: 10.1111/clr.13116

REVIEW ARTICLE

WILEY CLINICAL ORAL IMPLANTS RESEARCH

Papilla height in relation to the distance between bone crest and interproximal contact point at single-tooth implants: A systematic review

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Funding information
This Consensus Meeting was supported by a grant of the Osteology Foundation, Lucerne, Switzerland

Abstract

Objectives: The aim of this systematic review was to investigate the tooth–implant papilla formation in correlation with the distance between the interproximal bone level and the prosthetic contact point.

Material and Methods: A comprehensive search of the current literature (01/01/2000–01/01/2017) was performed to identify human trials that included 10 patients or more, with at least 12 months follow-up, in need of the replacement of one single tooth in the anterior maxillary region with an implant-supported single crown. To meet the inclusion criteria, studies had to provide both radiographic and clinical data regarding the distance between the interproximal bone level and the prosthetic contact point.

Results: The search yielded 136 records. After evaluation of abstracts and full texts, 12 papers were included in the final review, even though various reference points, for the comparison between the vertical distance and the papilla height, were used. The vertical distance between the interproximal bone level and prosthetic contact point ranged between 2 and 11 mm, and the partial or complete papilla fill (Jemt's score 2–3) ranged between 56.5% and 100% of cases.

Conclusion: There is limited evidence that the vertical distance from the base of the interproximal contact point to the crestal bone level seems to affect the interproximal papilla height; that is, the lower is the distance the higher is the percentage of papilla fill. Complete embrasure fill between an implant restoration and the adjacent tooth seems to be correlated with the integrity of the periodontal ligament of the tooth. To reduce the risk of aesthetic failures, interproximal probing on the adjacent teeth should be encouraged before implant placement.

KEYWORDS
dental implants, aesthetics, interdental papilla, interproximal soft tissue, papillae

1 | INTRODUCTION

Aesthetics has become, in the last decade, a key issue in contemporary implant dentistry (Buser, Chappuis, Belser, & Chen, 2017). One of the greatest challenges facing clinicians is to obtain an ideal soft tissue integration that mimics a perfect gingival contour, particularly in the interproximal area. In the early 90's, Tarnow, Magner, and Fletcher (1992) investigated the effect of the distance from the contact point to the crest of bone on the presence of the interproximal dental papilla and found out that when the measurement from the contact point to the

crest of bone was 5 mm or less, the papilla was present almost 100% of the time. Later on, the presence of the papilla between implants and teeth has received increasing attention due to the fact that successful therapy can no longer be judged by whether or not the implants osseointegrate (Papaspyridakos, Chen, Singh, Weber & Gallucci, 2012). In particular, some aesthetic evaluation scores have been introduced to objectify the peri-implant soft tissues outcomes (Fürhauser, Florescu, Benesch, Haas, Mailath, & Watzek, 2005; Jemt, 1997). Moreover, several authors have proposed surgical modifications and/or different loading protocols to obtain ideal soft tissue integration (Chen & Buser, 2014; Cosyn, Eghbali, Hermans, Vervaeke, De Bruyn, & Cleymaet, 2016). This is particularly difficult in compromised sites, caused by trauma, atrophy, periodontal disease, and/or infection (Zetu & Wang, 2005).

In recent years, a multitude of systematic reviews has been published in implant dentistry, all with very limited information regarding the achievement of successful results in the aesthetic zone. Notwithstanding guidelines for correct aesthetic treatment planning, based on the best available evidence, would be beneficial for every clinician.

Until now, however, there is no systematic review addressing the influence of the vertical distance between the interproximal contact point and the bone crest on the papilla height, in case an implant is placed in the aesthetic zone between two teeth.

The aim of this systematic review was to evaluate the evidence on the tooth–implant papilla formation in correlation with the vertical distance between the bone crest and the interproximal contact point at single-tooth implants.

2 | MATERIALS AND METHODS

The reporting of this systematic analysis adheres to the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) statement (Moher, Liberati, Tetzlaff, & Altman, 2009).

2.1 | Focus question

The following question was developed according to the population, intervention, comparison, and outcome (PICO) study design: "Does the vertical distance from the base of the interproximal contact point to the crestal bone level, at single implant adjacent to teeth, affect the interproximal papilla height."

2.2 | Search strategy

A comprehensive and systematic electronic search of both the MEDLINE–PubMed database and the Cochrane Central Register of Controlled Trials (CENTRAL) was conducted, for articles published in English between January 1, 2000 and January 1, 2017. The following free text terms were used ("single implant" AND "papilla").

Moreover, manual search of the bibliographies of all full-text articles and the following journals was conducted: "Clinical Oral Implants Research," "Clinical Implant Dentistry and Related Research," "European Journal of Oral Implantology," "Implant Dentistry," "International Journal of Oral & Maxillofacial Implants," "International Journal of Periodontics and Restorative Dentistry," "Journal of Clinical Periodontology," "Journal of Oral Implantology," "International Journal of Oral and Maxillofacial Surgery," "Journal of Periodontology," "Journal of Prosthetic Dentistry," "Open Dentistry Journal," "Journal of Implants and Advanced Clinical Dentistry."

The references of each relevant study were screened to discover additional relevant publications and to improve the sensitivity of the search.

2.3 | Population

Subjects in the included study must have had one single osseointegrated, solid screw-type implant in the maxillary anterior area (incisors, canines, and premolars) restored with an implant-supported single crown. All timing of implant placement, Type I-IV according to Hämmerle, Chen, and Wilson (2004), were included.

2.4 | Inclusion and exclusion criteria

The inclusion criteria are the following:

Randomized controlled clinical trials (RCT), prospective cohort studies, retrospective studies, cross-sectional studies, and case series studies, evaluating interproximal papilla height in relation to the radiographic distance from the contact point to interproximal bone, on a minimum of 10 patients treated with a single implant-supported crown in the anterior maxilla, with a follow-up of 1 year or more after crown placement.

Exclusion criteria were the following ones:

1. Review papers, letters, editorials, PhD theses, and abstracts, in vitro and animal studies;
2. Languages other than English publications;
3. Studies including <10 patients;
4. Studies with a follow-up <12 months;
5. Articles not providing information on both clinical and radiographic data;
6. Articles including teeth other than maxillary incisors, canines, and premolars.

2.5 | Selection of studies

Titles and abstracts from this search were independently screened by two reviewers (A.R. and A.R.) based on the inclusion criteria. Following this, the two independent reviewers screened all selected abstracts for possible inclusion in the review and determined the selection of full-text articles. The full texts of all studies of possible relevance were than obtained for independent assessment by the reviewers. Any disagreement was resolved through discussion, consulting a third party when consensus could not be reached. The third party was an experienced senior reviewer (M.R).

The initial electronic search resulted in the identification of 131 titles from the Medline–Pubmed database and 26 titles from the Cochrane Central Register of Controlled Trials (CENTRAL). After

TABLE 1 List and reason for the excluded studies

Reference	Reason for exclusion
Cosyn et al. (2011); Cosyn et al. (2013); Gallucci et al. (2011a; Gallucci et al. (2011b); Guarnieri et al. (2015); Grandi et al. (2013); Hof et al. (2013); Kolinski et al. (2014); Khraisat et al. (2013); Kan et al. (2003); Patil et al. (2016); Van Nimwegen et al. (2015)	No radiographic evaluation
Galindo-Moreno et al. (2016); Kwon et al. (2009); Lops et al. (2008); Ryser et al. (2005); Romeo et al. (2008)	Not restricted to anterior maxilla
Bruno et al. (2014)	No radiographic evaluation after prostheses placement
De Kok et al. (2006)	No information about possible correlation between vertical distance and papilla presence

elimination of the duplicate titles and identification of five hand-searched articles, a total of 136 titles were considered for possible inclusion. Retrieval of the 136 abstracts and further evaluation led to 31 full-text articles being selected. Of the 31 full-text examined articles, 19 were excluded from the final analysis. The main reason for exclusion was that studies did not evaluate the radiographic vertical distance from the contact point to the bone (n = 12 articles), five studies were not restricted to the anterior maxilla, and two articles presented methodological faults (Table 1). Finally, 12 were identified for inclusion in the review.

Figure 1 illustrates the search process.

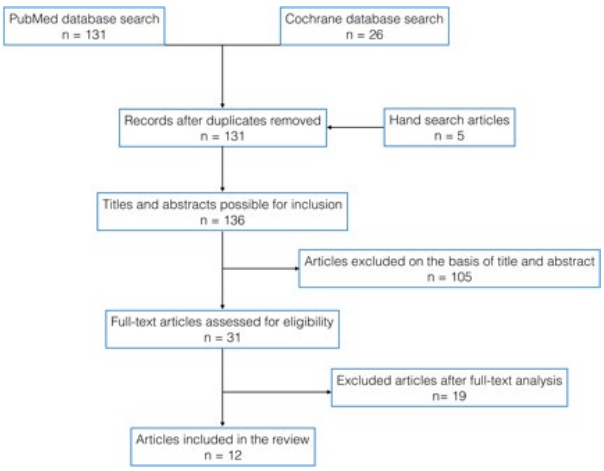


FIGURE 1 Flowchart of the included articles

2.6 | Data collection

From the 12 selected papers, general information on the study design, the setting where the investigation was conducted, the number of patients treated, and the number of implants placed were retrieved (Table 2).

Information regarding implant type, timing of implant placement, and loading was also extracted and presented in Table 3.

Clinical and radiographic data were retrieved for analysis (Tables 5–7). Mean values and standard deviations, where available, were extracted in duplicate by two reviewers (A.R. and A.R.).

2.7 | Quality assessment

The quality of included studies was assessed during the data extraction process (Table 4). All studies were considered to have a medium to high risk of bias.

2.8 | Data synthesis

Preliminary evaluation of the selected studies revealed that there was considerable heterogeneity among the studies with regard to study design, study population, and method of assessment of clinical and radiographic parameters. This considered that it was not possible to conduct a quantitative data synthesis, leading to meta-analysis. Nevertheless, authors attempted to report the data in order to perform a descriptive analysis.

3 | RESULTS

3.1 | Study characteristics

Collectively, 12 studies satisfied the inclusion criteria and were included in the review (Figure 1). None of the selected studies were randomized controlled clinical trials. Three studies were retrospective (Choquet, Hermans, Adriaenssens, Daelemans, Tarnow, & Malevez, 2001; Cosyn, Sabzevar, & De Bruyn, 2012; Perez, Segalla, Marcantonio Jr, Lauris, Ribeiro, & Ferreira, 2012), and six studies were prospective (Borges, Lima, Carvalho, Dourado, & Carvalho, 2014; Degidi, Nardi, & Piattelli, 2008; Henriksson & Jemt, 2004; Lops, Romeo, Chiapasco, Procopio, & Oteri, 2013; Lops, Mosca, Müller, Rossi, Rozza, & Romeo, 2011; Malchiodi, Cucchi, Ghensi, & Nocini, 2013), while three papers described data collected from cross-sectional clinical studies (Chang & Wennström, 2013; Nisapakultorn, Suphanantachat, Silkosessak, & Rattanamongkolgul, 2010; Palmer, Farkondeh, Palmer, & Wilson, 2007). Ten studies were conducted in a university (Borges et al., 2014; Chang & Wennström, 2013; Choquet et al., 2001; Cosyn et al., 2012; Henriksson & Jemt, 2004; Lops et al., 2011, 2013; Malchiodi et al., 2013; Nisapakultorn et al., 2010; Perez et al., 2012) one in private

practice (Degidi et al., 2008) and one in both of the settings (Palmer et al., 2007) (Table 2).

3.2 | Patient characteristics

Combining the samples size from each study, a total of 485 patients were included. The age of the patients ranged between 18 and 78 years. Two studies excluded smoking patients (Degidi et al., 2008; Lops et al., 2011), while other two studies excluded smokers >10 (Lops et al., 2013) and >20 (Malchiodi et al., 2013) cigarettes per day. Only one study (Choquet et al., 2001) included two smokers (>20 cig./day), whereas the remaining seven studies did not report on patients' smoking habit (Borges et al., 2014; Chang & Wennström, 2013; Cosyn et al., 2012; Henriksson & Jemt, 2004; Nisapakultorn et al., 2010; Palmer et al., 2007; Perez et al., 2012).

Nine of 12 studies did not report on patients' periodontal status (Chang & Wennström, 2013; Choquet et al., 2001; Cosyn et al., 2012; Henriksson & Jemt, 2004; Lops et al., 2013; Malchiodi et al., 2013; Nisapakultorn et al., 2010; Palmer et al., 2007; Perez et al., 2012), while three studies excluded patients with a history of periodontitis (Borges et al., 2014; Degidi et al., 2008; Lops et al., 2011).

Systemically healthy patients were included in four studies (Degidi et al., 2008; Lops et al., 2011, 2013; Malchiodi et al., 2013). The remaining eight studies did not report on the status of patients' general health (Borges et al., 2014; Chang & Wennström, 2013; Choquet et al., 2001; Cosyn et al., 2012; Henriksson & Jemt, 2004; Nisapakultorn et al., 2010; Palmer et al., 2007; Perez et al., 2012).

3.3 | Implant characteristics

In total, 531 implants of various brands were included in the present review. All selected studies, except Perez et al. (2012), presented data around bone-level implants (Borges et al., 2014; Chang & Wennström, 2013; Choquet et al., 2001; Cosyn et al., 2012; Degidi et al., 2008; Henriksson & Jemt, 2004; Lops et al., 2013; Malchiodi et al., 2013; Nisapakultorn et al., 2010; Palmer et al., 2007), while only one compared bone to tissue level implants (Lops et al., 2011). Moreover, implants with different surfaces were included. In particular, besides one study (Perez et al., 2012), which did not specify the implant system used and consequently the implant surface, all the other 11 studies used turned-surface implants (Choquet et al., 2001; Henriksson & Jemt, 2004) (n = 45) or moderate to rough surfaces (Borges et al., 2014; Chang & Wennström, 2013; Cosyn et al., 2012; Degidi et al., 2008; Lops et al., 2011, 2013; Malchiodi et al., 2013; Nisapakultorn et al., 2010) (n = 440). When analyzing the type of implant placement four studies considered delayed placed implants only (Borges et al., 2014; Chang & Wennström, 2013; Choquet et al., 2001; Henriksson & Jemt, 2004) (n = 115), three studies reported data on immediate placed implants only (Lops et al., 2011, 2013; Malchiodi et al., 2013) (n = 135), while two of the 12 studies combined delayed and immediate placed implants (Cosyn et al., 2012; Degidi et al., 2008) (n = 86; n = 63). Finally, three studies did not report the time of implant placement (Nisapakultorn et al., 2010; Palmer et al., 2007; Perez et al., 2012) (n = 132). Regarding peri-implant probing depth, only

TABLE 2 General information of the selected studies

Author	Study design	Setting	Patients	Implants	Age (Range)		Smokers	PCP	Systemic condition
Choquet et al. (2001)	Retrospective cross-sectional	University	26	27	43	(21–68)	2 (>20/d)	NR	NR
Henriksson and Jemt (2004)	Prospective	University	18	18	26.1	NR	NR	NR	NR
Palmer et al. (2007)	Cross-sectional	University & private practice	46	46	Uni: 21–56 Priv: 18–56		NR	NR	NR
Degidi et al. (2008)	Prospective	Private practice	45	52	41	(18–70)	Excluded	No	Healthy
Nisapakultorn et al. (2010)	Cross-sectional	University	45	40	45.2	(18–70)	NR	NR	NR
Lops et al. (2011)	Prospective	University	40	50	47.2	NR	Excluded	No	Healthy
Perez et al. (2012)	Retrospective	University	50	46	NR	(21–71)	NR	NR	NR
Cosyn et al. (2012)	Retrospective cohort	University	46	97	NR	NR	NR	NR	NR
Malchiodi et al. (2013)	Prospective	University	58	64	39.9	NR	<20/d	NR	Healthy
Chang and Wennström (2013)	Cross-sectional	University	58	32	47.2	(19–78)	NR	NR	NR
Lops et al. (2013)	Prospective cohort	University	21	21	42	(21–71)	<10/d	NR	Healthy
Borges et al. (2014)	Prospective	University	32	38	49	NR	NR	No	NR

NR, not reported.

TABLE 3 Information about implant type, timing of placement, and loading

Author	Implant type	Type of implant placement	Time of implant loading
Choquet et al. (2001)	Branemark	Delayed	Delayed (6 month)
Henriksson and Jemt (2004)	Standard or Mk Branemark	Delayed	Delayed (6 month)
Palmer et al. (2007)	Astra Tech AB	NR	NR
Degidi et al. (2008)	XiVE, DENTSPLY	37 (71.1%) immediate, 15 (28.9%) delayed	Immediate temporary restoration; 9- to 12-month final restoration
Nisapakultorn et al. (2010)	Paragon (Zimmer Dental), Astra Tech AB, Straumann, SteriOss, Replace (Nobel Biocare), Frialit-2 (Friadent)	NR	NR
Lops et al. (2011)	Astratech Microthread, Straumann StandardPlus	Immediate	8-week temporary restorations; 3-month final restorations
Perez et al. (2012)	NR	NR	NR
Cosyn et al. (2012)	Replace Select, Nobel Biocare	26 immediate, 71 delayed	Delayed (3–6 month)
Malchiodi et al. (2013)	Fast bone regeneration (FBR)-coated implants; coated with platelet-like bonded calcium phosphate (CaP) crystals	Immediate	Immediate nonfunctional loading, 6-month final restorations
Chang and Wennström (2013)	Astra Tech AB	Delayed	Delayed (after 6 month)
Lops et al. (2013)	SLActive bone level, Straumann	Immediate	3-week temporary screw-retained crowns, 4-month final cemented crowns
Borges et al. (2014)	OsseoSpeedTM, AstraTech	Delayed	6- to 10-week screw-retained resin provisional crowns. 2-month final restorations

TABLE 4 Assessment of the risk of bias for included studies

Author	Random sequence generation	Allocation concealment	Blinding	Incomplete outcome data	Selective reporting	Other bias
Choquet et al. (2001)	n.a.	?	?	–	+	+
Henriksson and Jemt (2004)	n.a.	?	?	–	+	+
Palmer et al. (2007)	n.a.	?	?	+	+	+
Degidi et al. (2008)	n.a.	?	?	+	+	+
Nisapakultorn et al. (2010)	n.a.	?	?	+	+	+
Lops et al. (2011)	n.a.	?	?	+	+	+
Perez et al. (2012)	n.a.	?	?	+	+	+
Cosyn et al. (2012)	n.a.	?	?	–	+	+
Malchiodi et al. (2013)	n.a.	?	?	–	+	+
Chang and Wennström (2013)	n.a.	?	+	+	+	+
Lops et al. (2013)	n.a.	?	?	+	+	+
Borges et al. (2014)	n.a.	?	?	+	+	+

n.a.: not applicable; + : low risk; ? : unclear risk; – : high risk.

four papers provided such information (Chang & Wennström, 2013; Choquet et al., 2001; Degidi et al., 2008; Palmer et al., 2007) (Table 5).

3.4 | Implant loading and restoration

When analyzing the type and the timing of loading, five studies considered implants temporary restored with a time range between immediate and 10 weeks within the implant placement and finally restored with a time range from 2 to 12 months after implant placement (Borges et al., 2014; Degidi et al., 2008; Lops et al., 2011, 2013; Malchiodi et al., 2013). Four studies reported data on delayed implants not previously provisionally restored (3 to 6 months) (Chang & Wennström, 2013; Choquet et al., 2001; Cosyn et al., 2012; Henriksson & Jemt, 2004). Finally, three of the 12 included studies did not provide information

TABLE 5 Measurements of the vertical distance. (a) Studies evaluating vertical distance from the contact point to the interproximal bone level next to the adjacent tooth. (b) Studies evaluating vertical distance from the contact point to the interproximal bone level. (c) Studies evaluating vertical distance from the contact point to the reference point. (d) Studies evaluating vertical distance from the contact point to the bone level at implant

Author, year	Vertical distance mean ± *SD* (range) mm	PPD mean ± *SD* (range) mm
(a)		
Choquet et al. (2001)	6.29 ± 2.25	3.36 ± 1.26
Henriksson and Jemt (2004)	5.9 ± 2.25 (2.0–11.0)	NR
Palmer et al. (2007)	NR	2.63 ± 0.92
Nisapakultorn et al. (2010)	5.1 ± 1.1 (2.9–9)	NR
Lops et al. (2011)		
Test:	M 5.9 ± 1.9	NR
	D 5.6 ± 1.6	
Control:	M 5.3 ± 1.4	
	D 5.3 ± 1.4	
Lops et al. (2013)	M 4.54 ± 1.19	NR
	D 4.35 ± 1.22	
Borges et al. (2014)		
Test:	M 5.71 ± 1.59	NR
	D 4.01 ± 1.76	
Control:	M 5.41 ± 1.84	
	D 4.11 ± 1.61	
(b)		
Degidi et al. (2008)	NR	Facial 2.6 ± 1
		Proximal 3.3 ± 0.9
Perez et al. (2012)	5.89	NR
Cosyn et al. (2012)	M 5.2 ± 1.9	NR
	D 5.0 ± 2.0	
Malchiodi et al. (2013)	4–4.9 (19 implants (29.7%))	NR
	5–5.9 (21 implants (32.8%))	
	6–6.9 (21 implants (32.8%))	
	>7 (3 implants (4.7%))	
(c)		
Chang and Wennström (2013)	6.9 ± 2.4 (2.5–12.3)	Facial 3.3 ± 1.1
		Proximal 3.9 ± 1.2
(d)		
Henriksson and Jemt (2004)	9.9 ± 2.78 (4.5–16.5)	
Palmer et al. (2007)	NR	
Nisapakultorn et al. (2010)	8.8 ± 1.9 (3.7–13.1)	

M = mesial; D = distal; NR = not reported.

about the timing of loading and the type of restorations (Nisapakultorn et al., 2010; Palmer et al., 2007; Perez et al., 2012). The overall time of the final restoration ranged from 2 to 12 months. Finally, it has to be underlined that none of the selected studies reported on the potential effect of timing of loading on the interproximal papilla height.

3.5 | Measurements of the vertical distance

Periapical radiographs were used in all of the 12 included studies to assess the radiographic distance from the contact point to the crestal bone. However, the reference points used to measure this particular distance differed among the studies. In particular, seven of the studies (Borges et al., 2014; Choquet et al., 2001; Henriksson & Jemt, 2004; Lops et al., 2011, 2013; Nisapakultorn et al., 2010; Palmer et al., 2007) evaluated the vertical distance from the contact point to the interproximal bone level next to the adjacent tooth. Choquet et al., 2001 reported the mean vertical distance to be 6.29 mm, whereas slightly lower corresponding values of 5.9 and 5.1 mm were indicated by other authors (Henriksson & Jemt, 2004; Nisapakultorn et al., 2010). Borges et al., 2014 presented the vertical distance on the mesial and distal aspects in the test and the control groups, 5.71 and 4.01 mm for (Test), and 5.41 and 4.11 mm, respectively (test group: implants with zirconia and gold titanium abutments, control group: implants with customized metal abutments) (Table 5a). Similar values for the mesial and distal aspects were reported by Lops et al., 2011, 2013, ranging from 4.54 to 5.9 mm on the mesial, and from 4.35 to 5.6 mm on the distal aspects.

Four articles evaluated the radiographic vertical distance between the contact point and the interproximal bone level (Cosyn et al., 2012; Degidi et al., 2008; Malchiodi et al., 2013; Perez et al., 2012) (Table 5b). Based on the results of these studies, the mean vertical distance ranged between 5.0 and 5.89 mm. According to Malchiodi et al., 2013, the majority of the 46 implants (65.6%) exhibited similar values ranging from 5 to 6.9 mm, 19 implants (29.7%) ranged 4 to 4.9 mm, while the last three implants (4.7%) had a vertical distance from the contact point to the bone adjacent to tooth >7 mm.

Chang & Wennström, 2013 measured the distance from the apical border of the contact area to the crowns to the reference line, drawn through the marginal corner of the implant shoulder (Table 5c). The mean value of this vertical distance was recorded to be 6.9 mm.

Three of the included studies (Henriksson & Jemt, 2004; Nisapakultorn et al., 2010; Palmer et al., 2007) evaluated the distance "contact point–bone level at the implant" (Table 5d). The mean of this distance was reported to be 8.8 mm (Nisapakultorn et al., 2010) and 9.9 mm (Henriksson & Jemt, 2004). Finally, Palmer et al., 2007 did not provide the mean values of the evaluated distance from the contact point to the bone at the adjacent to tooth, and adjacent to the implant. Table 6 reports the various methods of papilla evaluation in the selected papers.

Finally, due to an open contact between the implant crown and adjacent tooth, 28 patients (Palmer et al., 2007; —20 patients, Cosyn et al., 2012; —seven patients, Borges et al., 2014; —one patient)

TABLE 6 Papilla evaluation in the selected papers. (a) Studies using Jemt index (scores 0–4). (b) Studies evaluating papilla as present (score 1) or absent (score 0). (c) Studies using Fürhauser index: absent papilla (score 0), half present papilla (score 1), present papilla (score 2). (d) Studies measuring distance between the papilla tip and the contact point

(a) Author	Score 0 (%)	Score 1 (%)	Score 2 (%)	Score 3 (%)	Score 4 (%)
Choquet et al. (2001)	4 (7.7)	2 (3.8)	16 (30.8)	30 (57.7)	0 (0)
Henriksson and Jemt (2004)	0 (0)	0 (0)	M 8 (53)	M 7 (47)	0 (0)
			D13 (87)	D 2 (13)	
Palmer et al. (2007)	0 (0)	6 (6)	41 (45)	45 (49)	0 (0)
Degidi et al. (2008)	0	14.52%	50%	35. 48%	0 (0)
Nisapakultorn et al. (2010)	8 (11)		39 (53)	27 (36)	0 (0)
Perez et al. (2012)	3 (6.52)	17 (36.96)	9 (19.57)	17 (36.96)	0 (0)
Chang and Wennström (2013)	0 (0)	5 (9)	29 (53)	21 (38)	0 (0)

(b) Author	Score 1	Score 0
Lops et al. (2011) (%)		
Test:	M 18 (72)	7 (28)
	D 15 (60)	10 (40)
Control:	M 16 (64)	9 (36)
	D 13 (52)	12 (48)
Lops et al. (2013) (%)		
Test:	M 16 (76)	5 (24)
Control:	D 15 (71)	6 (29)
Mean papilla value	2.35 (0.56)	D 0.54 (2.38)

(c) Author		Score 0	Score 1	Score 2
Cosyn et al. (2012)	NR	NR	NR	NR
Borges et al. (2014)	Test:	0 (0)	17 (34%)	33 (66%)
	Control:	4 (18.2%)	13 (59.1%)	5 (22.7%)
Mean papilla score	Test:	1.6 6 ± 0.48		
	Control:	1.05 ± 0.65	(p < .001)	

(d) Author	Distance between papilla tip and contact point mean±*SD* (range) mm	
Malchiodi et al. (2013)	M	0.6 ± 0.5 (0.0–2.0)
	D	0.8 ± 0.6 (0.0–2.0)
	Mean	0.7 ± 0.6 (0.0–2.0)
		0–0.5 mm – 32 (50%) implants 1 mm – 18 (28.1%) implants 1.5 mm – 10 (15.6%) implants 2 mm – 4 (6.3%) implants

NR = not reported; M = mesial; D = distal.

and 13 proximal sites (Chang & Wennström, 2013; —seven sites, Nisapakultorn et al., 2010—six sites) were excluded from further evaluation.

3.6 | Papilla fill in relation to the vertical distance

Five of seven studies, which applied Jemt's score to evaluate interproximal papilla, found a correlation between the vertical distance "contact point–crestal bone" and papilla fill (Chang & Wennström, 2013; Choquet et al., 2001; Nisapakultorn et al., 2010; Palmer et al., 2007; Perez et al., 2012). Four of them reported this relation to be statistically significant (Chang & Wennström, 2013; Nisapakultorn et al., 2010; Palmer et al., 2007; Perez et al., 2012).

In particular, Choquet et al., 2001 found that, when the distance from the contact point to the bone crest was 3 to 4 mm, the papilla was fully present or almost fully present. A clear shift was noticed at the distance of 5 to 6 mm, with the missing papilla being present in 50% of the time (Table 7a).

TABLE 7 (a) Mean vertical distance ± *SD* in mm and papilla status using Jemt's index. (b) Percentage of papilla fill Jemt's 2 and 3 score. (c) Presence of papilla in relation to CPB[a]: absence (0) or presence (1) of papilla. d) Association of the papilla presence using Fürhauser's index: absent papilla (0), half present papilla (1), present papilla (2)

(a) Author		Score 0	Score 1	Score 2	Score 3	Significance
Choquet et al. (2001)		9.25 ± 1.15	5.76 ± 0.56	6.23 ± 0.89	5.95 ± 2.37	NR
Palmer et al. (2007)						
Bone level at implant	M	–	10.10 ± 2.22 (9.18–11.02)		8.30 ± 2.00 (7.39–9.21)	$p = .002$
	D	–	8.50 ± 2.11 (7.59–9.42)		7.15 ± 1.68 (6.42–7.87)	$p = .023$
Bone level at tooth	M	–	6.92 ± 2.11 (6.05–7.79)		5.17 ± 1.19 (4.63–5.71)	$p < .001$
	D	–	6.24 ± 1.70 (5.50–6.97)		5.35 ± 1.29 (4.79–5.90)	$p = .084$
Nisapakultorn et al. (2010)						
Bone level at tooth			6.2 ± 1.5	5.1 ± 1.0	4.7 ± 0.9	$p < .05$, $p < .01$
Bone level at implant			9.2 ± 1.9	9.0 ± 1.8	8.3 ± 2.0	$p > .05$
Perez et al., 2012		8	7.03	5.06	4.82	$p = .0223$
Chang and Wennström (2013)		–	5.7		4.3	$p < .01$

(b) Author	Vertical distance (mm)	<3	3	4	5	6	7	8	9	≥10
Henriksson and Jemt (2004)	Baseline	33	50	17	50	67	25	50	-	100
	1 year	100	100	100	100	100	100	100	-	100
Degidi et al. (2008)		<3	3.01 < x <4	4.01 < x <5	5.01 < x <6	5.01 < x <6		6.01 < x <7	>7	
	6 months	100	81	86	50	79		86	100	
	4–6 years	100	83	93	78.6	91		89	50	

(c) Author	Vertical distance	3–5 mm (%)	5–7 mm (%)	>7 mm (%)
Lops et al. (2011)				
Test:	Score 1	12 (92.3)	16 (55)	5 (62.5)
	Score 0	1 (-)	13 (45)	3 (37.5)
Control:	Score 1	14 (66.6)	14 (66.6)	4 (50)
	Score 0	7 (33.4)	7 (33.4)	4 (50)

(d) Author	Vertical distance	2–3 mm (%)	3–5 mm (%)	5–7 mm (%)	>7 mm (%)
Borges et al. (2014)					
Test:	Score 1				
	M	0 (0)	3 (37.5)	2 (25)	3 (37.5)
	D	2 (22.2)	0 (0)	4 (44.4)	3 (33.3)
	Score 2				
	M	0 (0)	6 (35.3)	10 (58.8)	1 (5.9)
	D	6 (37.5)	4 (25.0)	6 (37.5)	0 (0)
Control:	Score 1				
	M	0 (0)	3 (42.9)	4 (57.1)	0 (0)
	D	1 (16.7)	2 (33.3)	2 (33.3)	1 (16.7)
	Score 2				
	M	0 (0)	1 (50.0)	1 (50.0)	0 (0)
	D	1 (25)	3 (75.0)	0 (0)	0 (0)
					$p > .05$

M = mesial; D = distal; NR = not reported.
[a]CPB = distance between the interproximal bone level next to adjacent tooth and the contact point.

The vertical distance between the contact point and the bone level on the mesial aspect showed statistically significant greater measurement for Jemt scores 1 and 2 at both implant and tooth ($p < .01$) in comparison with the values in the group presenting Jemt score 3 (Palmer et al., 2007). The differences were found to be less on the distal aspect, but were statistically significant at the implant ($p = .023$), but not significant at the tooth ($p = .084$). The authors indicated a critical value for a complete papilla to be 6 mm from the tooth-associated bone crest to the contact point (complete papilla 95% CI 94.93–5.94 mm, deficient papilla 5.94–6.94 mm) and the corresponding critical value when measured from the implant-associated bone crest was 8.5 mm (complete papilla 95% CI 7.20–8.75 mm, deficient papilla 8.55–9.77 mm) (Palmer et al., 2007).

Similar findings were reported by Nisapakultorn et al., 2010, where the distances from the contact point to the bone next to adjacent tooth for the Jemt scores 0 and 1 were significantly greater than those of the papilla scores of 2 ($p < .05$) and 3 ($p < .01$). In contrast to the findings to the previous study (Palmer et al., 2007), authors did not find the bone next to the implant to be significantly related to the papilla fill.

Studies by Perez et al., 2012 and Chang & Wennström, 2013 indicated a significant influence of the vertical distance on the presence of the papilla, pointing out that the distance "crown contact point–crestal bone" was statistically significantly shorter for "complete papilla" corresponding to Jemt score 3 than that for "deficient papilla" corresponding to Jemt scores 1 and 2, 4.3 and 5.7 mm, respectively ($p < .01$) (Chang & Wennström, 2013).

Two studies (Degidi et al., 2008; Henriksson & Jemt, 2004) evaluated papilla fill at the baseline (after the placement of the final restoration) and at the final follow-up (Table 7b). More in details, Henriksson & Jemt, 2004 noticed a significant increase in the "presence" papilla during the 1-year follow-up ($p < .01$). However, authors were not able to reveal a correlation between the papilla index score and the distance between bone at the adjacent tooth and the bone next to an implant, and contact point ($p > .05$). These results are in line with the findings of Borges et al., 2014; study, who confirmed an absence of significant correlation between the vertical distance "contact point–bone adjacent to tooth" and papilla fill (Table 7d).

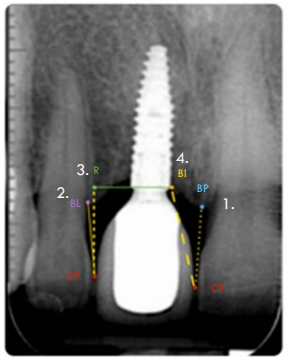
In the clinical study with a longer follow-up (4–6 years), it was reported that although a general papilla height increase was observed, this growth was sufficient to improve the Jemt index score in only 18% of the cases (Degidi et al., 2008). In the later study, a good aesthetic outcome (Jemt score 2 or 3) was observed when the contact point between the crown of the prosthetic tooth and the crown of the natural tooth was placed ≤7 mm from the bone peak (Table 7b).

The results of a study by Lops et al., 2011 demonstrated that the vertical distance from the contact point to the bone level at the adjacent tooth was related to the papilla presence only when it was associated with the interimplant–tooth distance of 2.5–4 mm, and this finding was valid only for AstraTech implants (Table 7c).

In addition, Lops et al., 2013 reported the presence of the mesial papilla to be significantly correlated with the mean mesial distance from the contact point to the bone adjacent to tooth, while in a contrary, Cosyn et al., 2012 demonstrated that the recession of the distal papilla was affected by the distance of the bone peak to the contact point. Finally, Malchiodi et al., 2013 found a significant correlation

TABLE 8 Conclusions suggested by the authors

Author	Conclusions
Choquet et al. (2001)	The regeneration of papilla is possible when the contact point is 5 mm from the crest. Above 5 mm, papilla regeneration is at least 50%, but with no predictability
Henriksson and Jemt (2004)	No relationship could be observed between the papilla index score and the distance between bone crest and contact point
Palmer et al. (2007)	Presence (Jemt score 3) or deficiency (score 1/2) of the papilla was significantly related to the distance from the contact point to the bone level on the adjacent tooth.
Degidi et al. (2008)	The contact point between the natural tooth and the restoration crown should be ≤7 mm from the bone peak
Nisapakultorn et al. (2010)	The distance from the contact point to the alveolar bone crest of the adjacent tooth was a significant factor that influenced the level of papilla fill.
Lops et al. (2011)	Vertical distance was significantly related to the papilla presence only when it was associated with horizontal distance values of 2.5–4 mm and this finding was only for AstraTech implants (Test group).
Perez et al. (2012)	There is a significant influence of the distance between the bone crest and interproximal contact point on gingival papilla height.
Cosyn et al. (2012)	Recession of the distal papilla was affected by the distance of the bone peak to the contact point.
Malchiodi et al. (2013)	Statistically significant correlation between interproximal crest levels and interproximal papilla volume.
Chang and Wennström (2013)	The vertical distance from the contact point to the bone level at the adjacent tooth significantly influence the presence of papillae.
Lops et al. (2013)	The relationship between the presence of a complete interproximal papilla and the vertical distance from the contact point to the bone still remains unclear
Borges et al. (2014)	No significant presence of papilla was found in relation to the distance from the base of the contact point to bone crest of adjacent tooth.



- Interproximal contact point (CP)
- Bone level at the adjacent tooth (BL)
- Inter proximal bone peak (BP)
- Bone level at the reference point at implant level (R)
- Bone level at the implant (BI)

1. Contact Point - Bone Peak
(Degidi et al 2008; Perez et al 2012; Cosyn et al 2012; Malchiodi et al. 2013)

2. Contact Point - Bone level at the adjacent tooth
(Choquet et al. 2001; Henriksson & Jemt 2004; Palmer et al. 2007; Nisapakultorn et al. 2010; Lops et al 2011; Lops et al 2013; Borges et al. 2014)

3. Contact Point - Reference point (Chang & Wennstrom et al 2013)

4. Contact Point - Bone level at the implant (Henriksson & Jemt 2004; Palmer et al. 2007; Nisapakultorn et al. 2010)

FIGURE 2 Schematic drawing showing the selected reference points and the measured distances in the 12 selected studies

between the distance "contact point–bone crest" and "papilla tip–contact point."

All results are summarized in Tables 2–8. Figure 2 illustrates the different reference points used by the authors in the selected articles.

4 | DISCUSSION

The aim of this systematic review was to investigate the current level of clinical evidence on the papilla height related to the vertical distance from the contact point to the interproximal bone peak, at single-tooth implants. Even though all the 12 included papers considered the interproximal contact point as one of the two reference points, four bone-related landmarks were detected: bone peak; bone level at the adjacent tooth; reference point; and bone level at the implant site. As consequence of this heterogeneity, it was not possible to combine data.

Besides the use of different landmarks, one of the most critical issues is the precise evaluation, on the radiographic image, of the exact position of the interproximal contact point, due to the radiolucent nature of the ceramic crown. Only Henriksson and Jemt (2004), Palmer et al. (2007), and Nisapakultorn et al. (2010) placed a 0.25-mm orthodontic wire apical to each contact point (when present) and tightened it to demarcate the position of the contact point on the radiograph before the radiographic exposure, while Perez et al. (2012) placed 1-mm-diameter metal marks in the region corresponding to the interdental contact point. It is hard to understand how the other authors were able to overcome this difficulty. Moreover, interpretation of radiographs is difficult (Meijer, Steen & Bosman, 1993) and most likely measurements were affected by significant errors. For example, Borges et al. (2014) presented radiographs with an overlapping zone between the tooth and the implant crown and accepted the medium point in the overlapping zone for effects of measurement of CPB values.

All this taken into account, the analysis of the selected literature therefore does not allow to indicate which is the type of surgical procedure and/or prosthetic rehabilitation most suitable for obtaining optimal results.

Ideally, systematic reviews should give clinicians indications to provide patients with therapeutic solutions based on the best available evidence. No data are available to suggest an ideal apico-coronal positioning of the implant and its effects on the papilla height/embrasure fill. Thus, due to the lack of additional scientific information, the positioning of the implant shoulder should still follow the philosophy "as shallow as possible, as deep as necessary," as a compromise between aesthetic and biologic principles (Buser, Martin & Belser, 2004).

Several clinical factors, listed in Figure 3, have been suggested to influence the papilla height. The most clinically relevant one seems to be the level of the periodontal ligament of the adjacent tooth which, in most of the included studies, was assessed by radiographic bone levels and only in three of them also by periodontal probing. Moreover, among the selected studies, only one of them underlined its importance for an ideal papilla height. Indeed, Chang and Wennström (2013) concluded that the "maintenance of the periodontal support at the

Integrity of the PDL of the adjacent teeth
Diameter of the implant
Configuration of the collar of the implant
Implant-tooth distance M-D (proximity)
Dimension of the missing gap
Implant abutment connection
Bucco-palatal position
Crestal bone thickness
Natural teeth morphology & location
Gingival bio-type

FIGURE 3 Potential factors influencing papilla height not related to CPB distance

adjacent teeth is critical for the long-term stability of the proximal soft tissue level next to a single implant-supported restoration." Its importance has been recently confirmed by Cosyn, Thoma, Hämmerle, and De Bruyn (2017), who attributed credit to one of the selected articles (Choquet et al., 2001) to correlate "the embrasure fill between an implant restoration and the adjacent tooth to the vertical position of the periodontal attachment of the adjacent tooth." In reality, Choquet et al. (2001) came to the conclusions that "the papilla level around single-tooth implant restorations is mostly related to the bone level adjacent to teeth and more specifically to the bone crest." In the whole paper, "periodontal attachment loss" of the adjacent teeth is never mentioned. Therefore, due to the lack of data on this specific aspect, no definitive conclusion can be made regarding a threshold probing value of the adjacent teeth to ensure an ideal tooth–implant papilla fill.

Moreover, smoking and periodontal diseases are commonly correlated with a higher number of aesthetic failures, especially when the two risk factors are associated in the same patient (Zangrando et al., 2015). Even though it seems reasonable to avoid smoking and to control the periodontal disease for an optimal papilla fill, it is not possible, however, to draw any definitive conclusion with the data presented in the selected papers.

In addition, papilla fill does not seem related to whether the prosthetic crown is positioned immediately following surgery or only after soft tissues have healed.

Finally, it must be mentioned that one limitation of this SR is that the literature search could have been extended to other databanks with no language restrictions, even though the chances of missing significant information seem very limited.

5 | CONCLUSIONS

There is limited evidence that the vertical distance from the base of the interproximal contact point to the crestal bone level, at single implant adjacent to teeth, seems to affect the interproximal papilla height.

As a general trend, the lower is the distance the higher is the percentage of papilla fill, even though it is not possible to set up a threshold value correlated with the complete presence of the papilla.

Complete embrasure fill between an implant restoration and the adjacent tooth seems to be related to the integrity of the periodontal ligament, as assessed by the radiographic bone levels in the studies included in this review.

No data are available to indicate which is the surgical procedure (i.e., submerged vs. nonsubmerged, immediate vs. delayed) most indicated for better results.

6 | CLINICAL RECOMMENDATION

To reduce the risk of aesthetic failures, interproximal probing on the adjacent teeth should be encouraged before implant placement to assess the vertical position of the periodontal attachment of the adjacent teeth.

The clinician should make every possible effort to prevent interproximal crestal bone loss in order to achieve the best possible aesthetic outcomes. However, postextraction implants and/or their immediate loading should not be considered as a mean to obtain this, in cases of single-tooth restoration.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests with respect to the publication of this article.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

How to cite this article: Roccuzzo M, Roccuzzo A, Ramanuskaite A. Papilla height in relation to the distance between bone crest and interproximal contact point at single-tooth implants: A systematic review. *Clin Oral Impl Res*. 2018;29(Suppl. 15):50–61. https://doi.org/10.1111/clr.13116