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REVIEW ARTICLE

Effect of the implant–abutment interface on peri-implant tissues: A systematic review

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Abstract

Objective. The aim of the present systematic review was to determine the peri-implant tissue response to different implant abutment materials and designs available and to assess the impact of tissue biotype. ***Materials and methods.*** Relevant literature published between December 2009 and August 2012 was searched to identify studies dealing with different implant abutment designs and materials, as well as the response of different tissue biotypes. The search terms used, in simple or multiple conjunctions, were 'implant abutment', 'interface', 'material', 'peri-implant', 'soft tissue' and 'esthetic'. Studies were selected according to pre-determined inclusion and exclusion criteria. ***Results.*** The initial search yielded 2449 titles. After a subsequent filtering process, 23 studies were finally selected. The included studies revealed different factors responsible for the stability of peri-implant tissue and the esthetic outcome. These factors include tissue biotype and architecture, implant abutment material and implant abutment design. Several designs were suggested to prevent marginal bone loss and soft tissue recession. These included scalloped implants, platform-switched implants and gingivally converged or concave implant abutments. Due to the limited number of studies and the heterogeneity in their designs, it was not possible to perform a statistical analysis of the data. ***Conclusions.*** The current literature provides insufficient evidence about the effectiveness of different implant abutment designs and materials in the stability of peri-implant tissues.

Key Words: *abutment, biotype, material and design, peri-implant interface*

Introduction

In the past 20 years, implant dentistry underwent significant developments [1–3]. Clinical experience and research with dental implants as well as the continued evolution of materials, techniques and their use enabled the expansion of treatment indications, which has been considered to be one of the most notable developments. Implant placement has been well documented in the treatment of completely and partially edentulous arches [4–6]. This encouraged clinicians to expand the indication spectrum to include also single tooth replacement [7,8].

Another important development has been the gradual shift in success criteria, as the focus became not only on achieving a successful osseointegration, but also on a variety of mechanical and esthetic challenges that remained problematic and unresolved, especially in the anterior zone [9]. In fact, the achievement of a healthy, harmonious and maintainable interface between the implant-supported restoration and the peri-implant tissue became a major concern. Therefore, attention is now focused on parameters that may influence the interaction between the implant and the surrounding hard and soft tissues, thus the long-term predictability of the esthetic outcome.

The healthy peri-implant tissues necessitate the integration of sound hard and soft tissues. The periosteum is a tissue that covers the external surface of bones and serves as a transitional region between bone and the overlying soft tissue. Anatomically, the peri-implant soft tissue consists of (a) a well keratinized oral epithelium that is continuous with a junctional epithelium and (b) a fiber-rich connective tissue [10]. It has been suggested that 2-mm width of the peri-implant mucosa is required to enable a proper epithelial and connective tissue attachment and is referred to as the 'Biological width' [11]. On the other hand, the appearance and maintenance of soft tissue architecture have been suggested to be influenced by

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the underlying bone [12]. The process of bone remodeling occurring following implant placement is defined by the continuous turnover of bone [13], which involves bone resorption continued by reactive bone formation [14]. Imbalance in the regulation of both resorption and deposition could lead to excessive bone resorption, which is thought to be detrimental for the stability of the overlying soft tissue [15]. Peri-implant bone remodeling is suggested to be multifactorial depending on the interaction of multiple variables. These factors include biological factors such as quality of the peri-implant tissue [16] and the presence or absence of a keratinized tissue [17]. The biomechanical factors include the implant-abutment interface (also known as the microgap) [18,19], the loading pattern, as well as the material and design of the implant abutment [20–24]. Other factors include the surgical procedure [25], the type of provisional restoration and the oral hygiene [26]. However, despite the presence of various studies focusing on these factors, the exact mechanism of bone remodeling around implants as well as the corresponding soft tissue appearance and architecture remain unclear.

In regards to the biomechanical factors, the implant abutment, which represents the transmucosal connection between the implant and superstructure, is considered to be one of the most important factors. It has been suggested that the abutment material as well as the design may play an important role on both the biological response and the esthetic outcome of the peri-implant tissues.

Because of its well-documented biocompatibility and mechanical properties, commercially pure titanium is being widely used for the transgingival components of dental implants [27]. In addition, several studies have reported promising results also with titanium alloys and modified titanium surfaces [28]. However, the color of these materials may be disadvantageous and cause esthetic problems due to the risk of the grey color of the metal component being visible, especially through thin peri-implant tissues [29]. As a result, ceramic abutments have been introduced to improve the esthetic results. In recent years, zirconia abutments have been favored with regard to the esthetic expectations, especially in the visible anterior region [30]. Here, it is noteworthy to mention that the mucosa thickness has been considered as a crucial factor in terms of discoloration, as it has been suggested that, with a mucosa thickness of 3 mm, no change in color of the surrounding peri-implant soft tissues can be distinguished with any type of material [22]. This has been recently contradicted by a clinical study which reported that discoloration in the peri-implant soft tissue occurs with all types of restorative materials regardless of the mucosa thickness, since a soft tissue thickness of 3 mm was considered impossible [31].

In regards to the design of the abutment, the implant-abutment interface is considered one of the primary determinants of prosthetic stability. The nature of this interface makes it sensitive to mechanical loading and bacterial contamination [32], which may give rise to many problems such as micromovements, loosening of abutment screws and microbial colonization [33]. Many designs of abutments, including interface, have been introduced in an attempt to overcome these problems. These designs include: scalloped implants, platform-switching and the gingivally converging abutments [34–36]. The literature presents controversies concerning the effectiveness of these different designs on the stability of peri-implant tissues. Therefore, it is important that use of new designs must be based on clinical evidence accomplishing that they are effective in what is claimed.

Basically, information regarding the response of hard and soft tissue to different implant abutment materials and designs is essentially lacking. Here, several concomitant questions can be raised and need to be answered:

(1) Is there a correlation between the quality of the peri-implant soft tissue and its long-term stability?
(2) What is the most appropriate design and material for both the abutment and restoration in terms of biological response and esthetic outcome of the peri-implant tissue?

Therefore, the aim of this review was to determine the peri-implant tissue response to different abutment materials and designs and to assess the impact on esthetics.

Materials and methods

Search strategy

An electronic search of the literature was performed between December 2009 and August 2012 to identify all articles investigating the addressed questions. Information about the biological response and esthetic outcomes of peri-implant tissues was retrieved. In the present article, the esthetic outcome was evaluated by several parameters such as changes in soft tissue color, harmonization of the soft tissue margins and marginal recession. The search was conducted using MEDLINE (National Library of Medicine)-Pubmed and Google scholar, without restrictions concerning the date of publication. Multiple keywords including abutment, interface, material, peri-implant, soft tissue and esthetic were used (connecting different keywords with AND, OR). This was followed by a manual search and references were used to identify relevant articles. A second electronic search was performed using additional keywords such as: biotype, microgap, scalloped

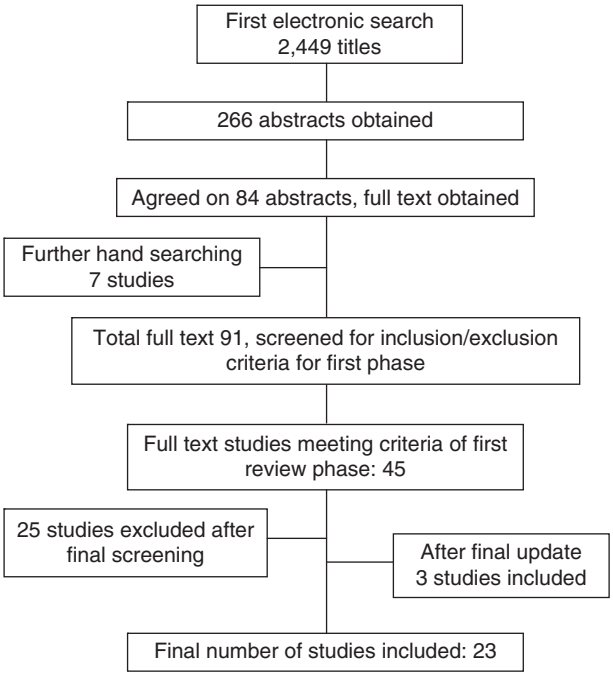

Figure 1. Search strategy and results.

implants and platform switching (Figure 1). The titles and abstracts of all articles identified from the electronic and manual search were screened by two reviewers to eliminate articles that clearly failed to meet the following inclusion and exclusion criteria:

Inclusion criteria

- Randomized controlled clinical trials, prospective and retrospective clinical studies.
- The mean follow-up time should be at least 1 year.
- At least 10 patients were included in each study.

Exclusion criteria

- *In vitro* and animal studies, as well as case reports or case studies.
- Studies in a language other than English or without an English abstract.
- When multiple reports of the same study were identified, only the most recent report was included.

Results

The initial database search yielded 2449 studies, 45 studies passed the first review phase and 23 studies were finally selected after screening on the basis of the inclusion and exclusion criteria. The publication date of the studies ranged between 1996–2012, with the majority released after 2003. The excluded studies and reasons for their exclusion are listed in Table I.

The 23 articles were categorized with respect to their context on tissue biotype, abutment design and material. A detailed description of the studies related to each factor is provided below:

Soft tissue biotype

Tissue biotype, which defines the thickness of the soft tissue in a bucco-lingual dimension, has been classified as being either thick or thin [37]. Tissue biotype is usually coined with different architecture types. Tissue architecture or scallop, defined as the distance between the contact point between two neighboring teeth and a line connecting the mid-facial soft tissue margin of these teeth, has been categorized as flat or scalloped [38].

The literature search yielded three studies referring to the effect of tissue biotype on the surrounding peri-implant tissues (Table II). Only tissue biotype was identified in the studies with no concern to tissue scalloping. The criteria used to evaluate the tissue biotype were heterogeneous. However, two studies evaluated the influence of the tissue biotype on gingival recession. Here, tissue biotype was identified through the visibility of the periodontal probe. It was considered thin if the probe showed through and thick if it couldn't be seen through the soft tissues. Both studies revealed that sites with thin tissue biotype had a higher frequency of recession of 1 mm or more in comparison to areas with thick tissue biotype [39,40].

The third study, which was prospective in its design and evaluated the influence of soft tissue thickness on the underlying marginal bone, reported a mean bone loss of 1.45 mm in areas with thin biotype. On the other hand, areas with thick biotype showed a mean bone loss of 0.17 mm [12].

Abutment material

The literature search revealed five studies relevant to the response of peri-implant tissues to the abutment material. Three of which were RCTs, whereas the other two were prospective studies (Table III).

Two randomized controlled trials evaluated the esthetic response of peri-implant tissues to different abutment materials over a period of 36 months. The esthetic response was evaluated through color assessment and soft tissue thickness. One study included also the papilla height as one of the parameters to assess the esthetic response. The authors reported that both zirconia and titanium abutments induced negatively a visible change in color. Although all-ceramic restorations showed a better color match than metal-ceramic restorations, no significant difference was found between both. Similarly, there was no significant difference also in terms of soft tissue thickness and papilla height [41,42].

In regards to the biological response of peri-implant tissues to different abutment materials, the

Table I. Excluded studies after final screening and reason for exclusion.

Exclusion criteria/studies	Year
No differentiation between thin and thick biotype	
Bengazi et al. [89]	1996
Cardaropoli et al. [90]	2006
Kan et al. [16]	2003
Non-clinical studies	
Berglundh et al. [91]	1996
Conte et al. [92]	2002
Jovanovic [93]	2005
Soadoun et al. [94]	2007
Kan et al. [64]	2003
Abrahamsson et al. [21]	1998
Jung et al. [22]	2007
Welander et al. [23]	2008
Scarano et al. [95]	2003
Tan et al. [96]	2004
Kohal et al. [97]	2004
Linkevicius et al. [98]	2008
Rimondini et al. [99]	2002
Abrahamsson et al. [100]	2007
Nothdurft et al. [101]	2009
Rompen et al. [36]	2007
Redemagni et al. [82]	2009
Luongo et al. [102]	2008
Gardner [46]	2005
Lopez-Mari et al. [83]	2009
Dibart et al. [103]	2005
Farronato et al. [104]	2012
Fewer than 10 patients	
Nowzari et al. [105]	2006
Observation period <1 year	
Vela et al. [106]	2012
Dursun et al. [107]	2011
Veis et al. [85]	2010

literature search yielded one RCT and two prospective studies.

A 5-year comparative study evaluating the response of peri-implant mucosa to different abutment materials was identified [43]. The study showed superiority of titanium over alumina abutments in terms of recession, with most of the changes being recorded during the first 2 years. The esthetic outcome was dependent on both clinician rating and patient's satisfaction. It was reported that 92% of all cases had good esthetic results with full satisfaction of the patients [43].

Another prospective study compared peri-implant hard and soft tissue response to gold and titanium abutments on single tooth implants [44]. It concluded that neither titanium nor gold alloy abutments were clinically or biologically superior.

The mean marginal bone loss around zirconia abutments was investigated in another prospective study, which showed a mean marginal bone loss of 1.1 mm and 1.2 mm after 1 and 4 years, respectively [45].

Abutment design

The search yielded 15 studies in regard to the implant abutment design, eight randomized controlled trials, five prospective studies and two retrospective studies (Table IV). The studies reported different commercially available implant abutment designs, such as the scalloped implants, platform switched and gingivally converging or concave abutments [35,36,46]. Platform switching refers to the use of an abutment with a diameter smaller than the implant body, leading to the inward repositioning of the implant-abutment interface horizontally, whereas the scalloped implant design is a modification where the form of the implant collar is designed with a morphology that imitates the anatomy of the hard and soft tissues around a natural tooth [46].

Twelve of the included studies evaluated the platform-switched implant abutments. Eight studies reported a significant difference in mean bone loss between the conventional and platform-switched design, whereas the soft tissue response was not evaluated [18,34,47–52]. One study showed a significant difference between conventional and platform-switched implants after 1 year, whereas no difference was reported between both groups after an observation period of 5 years [53]. Three other studies showed no significant difference in terms of marginal bone loss and peri-implant mucosal changes between the conventional and the platform-switched implants [20,54,55].

Scalloped implants were evaluated in three studies. One randomized controlled study evaluated the marginal bone loss around scalloped implants in comparison with conventional implants with either smooth or rough necks, after an observation period of 18 months. The rough neck implants showed the least amount of marginal bone loss (0.9 ± 0.57 mm). Although the scalloped implants had moderately rough neck surfaces, however, they showed the most extensive marginal bone loss when compared with the smooth group, with a loss of 2.01 ± 0.77 mm [56]. The other two studies, which were retrospective in nature, showed little or almost no recession of peri-implant soft tissue [57,58]. One study reported an annual decrease of 0.14 mm of marginal bone level after the second year of implant placement, with an average bone loss of 1.6 mm after an observation period of 65.2 months [57].

Table II. Included studies on the effect of soft tissue genotype on surrounding peri-implant tissues.

Study	Study type	Follow-up period	Sample size/no of implants	Type of implants	Implant placement protocol	Type of abutment/restoration	Tissue biotype	Results
Linkevicius et al. [12]	Prospective	1 year	19 patients/46 implants (23 test + 23 control)	Biohorizons	Delayed	standard abutments/PFM restorations	9 implants (thin <2 mm) 14 implants (thick >2 mm)	Mean bone loss 1.45 mm (thin biotype) 0.17 mm (thick biotype)
Evans et al. [39]	Retrospective	18.9 months	42 patients/47 implants	Straumann (25) Biomet (17)	Immediate	Abutment type: NR Restoration: PFM	Thick and thin areas (measured with show through of periodontal probe)	Mucosa recession 1 ± 0.9 mm (thin group), 0.7 ± 0.5 mm (thick group)
Romeo et al. [40]	Prospective	1 year	48 patients/48 implants (9 excluded)	Straumann	Immediate	Abutment: Straumann Synocta/Restoration: NR	25 implants (thick), 14 implants (thin) measured through visibility of periodontal probe	Papilla was present in 84% of implants with thick biotype, and in 42.8% of thin biotype

NR, not reported.

Discussion

The purpose of this systematic review was to determine the peri-implant tissue response to different implant abutment materials and designs available and to assess the possible impact of the tissue biotype on this response. Due to the heterogeneity of the studies (different observation periods, different types of studies), it was not possible to perform a statistical analysis of the data. The gold standard for systematic reviews is to study randomized clinical trials (RCT), which are the studies with the most robust design [59]. Most of the studies included in this review were RCTs and prospective studies. Prospective studies were classified in category B according to the strength of evidence and clearly indicate a higher quality of data compared with retrospective studies [60].

The results of this review showed that a correlation exists between gingival biotype and the susceptibility to gingival recession following surgical and restorative procedures. Gingival recession is considered the most common esthetic complication after implant placement, especially for single tooth replacement in the anterior region [61,62]. Therefore, evaluation of the soft tissue status is considered a pre-requisite before implant placement; Variations in gingival thickness have been related to different soft tissue biotypes, namely thick and thin. These tend to respond in a different way to inflammation or to surgery [63]. Thick tissue biotype is considered dense and fibrotic, thus more stable and resistant to recession [64]. However, a disadvantage of the thick biotype is the predisposition to form scars after the execution of vertical incisions [63]. Therefore, it is important to adequately value the type of incision or the flap that is going to be carried out for the placement of the implant [65]. On the other hand, thin tissue biotype is often delicate and more prone to recession and interproximal loss following any surgical procedure [66]. This feature can be attributed to thinner tissues being friable, less vascularized and accompanied with thinner underlying bone. In this context, it has been demonstrated that a clinically thin biotype is associated with a thin labial plate. This is associated with a significantly greater distance between the CEJ and the bony crest, which displays a narrower zone of keratinized tissues [67]. In implantology, the importance of a thick biotype is further reinforced because of the lack of a periodontal ligament that provides additional blood supply during wound healing [68]. Therefore, it appears reasonable that thick tissue would be a desirable feature around dental implants both for esthetic and functional benefits.

No clinical studies were found concerning the relationship between tissue scallop and biological response after implant placement. Nevertheless, it has been reported that tissue scallop and biotype cannot be separated from each other, since a thick

Table III. Included studies on the effect of implant abutment material on peri-implant tissues.

Study	Study type	Follow-up period	Sample size/no of implants	Type of implants	Implant placement protocol	Type of abutment/restoration	Tissue biotype	Results
Vigolo et al. [44]	Prospective	4 years	20 patients/40 implants	20 NobelBiocare, 20 Biomet	Late	20 titanium abutments, 20 gold abutments Restorations: PFM crowns	NR	Bone resorption 0.3–0.8 mm with both materials. No significant difference on peri-implant soft tissue. Effect on color not reported
Jung et al. [41]	RCT	36 months	30 patients/30 implants	Straumann	Late	15 Al_20_3 abutments, 15 titanium or gold abutments. Restorations: PFM on titanium & gold, All ceramic crowns on Al_20_3 abutments.	Thick >2 mm Areas less than 2 mm received a CT graft	All ceramic restorations on Al_20_3 abutments showed a better color match than PFM. Biological response not reported
Andersson et al. [43]	RCT	5 years	32 patients/105 implants, 30 patients/103 implants	Nobel Biocare	Late	53 ceramic abutments, 50 titanium abutments, Restorations 36 FPDs (19 on ceramic, 17 on titanium)	NR	Level of peri-implant mucosa showed differences in 12% of cases, 73% of all changes were recorded at ceramic abutments. Mean marginal bone loss 0.3 mm loss in ceramic, 0.4 mm loss in titanium
Zembic et al. [42]	RCT	3 years	22 patients/40 implants	Bränemark (Nobel Biocare)		20 Zirconia abutments, 20 Titanium abutments Allceramic crowns on Zirconia Metal ceramic crowns on Titanium	NR	No significant difference in bone level between two groups. Both Zirconia and Titanium induced a visible change in color, but no significant difference between both
Glauser et al. [45]	Prospective	4 years	27 patients/54 implants	Bränemark (Nobel Biocare)	Late	Zirconia abutments/Allceramic crowns	NR	Mean marginal bone loss 1.1 mm after 1 year, 1.2 mm after 4 years. Gingival recession not reported

NR, not reported; CT, connective tissue graft; PFM, porcelain fused to metal; FPD, fixed dental prosthesis; Al_20_3, aluminium oxide.

Table IV. Included studies on the effect of implant abutment design on peri-implant tissues.

Study	Study type	Follow-up period	Sample size/no of implants	Type of implants	Implant placement protocol	Type of abutment/restoration	Tissue biotype	Results
Cappiello et al. [18]	Prospective	1 year	44 patients/131 implants (75 PS, 56 NPS)	3i Biomet	Late	PFM crowns	NR	Peri-implant bone loss 0.95 mm PS group, 1.67 mm NPS group
Crespi et al. [20]	Prospective	24 months	45 patients/64 implants (34 NPS, 30 PS)	Ankylos Dentsply implants	Immediate	PFM crowns	NR	After 2 years, marginal bone loss 0.78 mm NPS group, 0.73 mm PS group
Trammell et al. [47]	RCT	2 years	10 patients/ 25 implants	3i Biomet	NR	NR	NR	Mean bone loss 1.19 mm NPS group, 0.99 mm PS group
Canullo et al. [48]	RCT	25 months	22 patients/22 implants (11 NPS, 11 PS)	NR	Immediate	PFM crowns	11 thick 11 thin	No significant difference between PS and NPS groups. No significant difference between thick and thin tissue biotypes
Vigolo et al. [53]	Prospective	5 years	144 patients/182 implants (85 NPS, 97 PS)	3i Biomet	Late	PFM with gold abutments	NR	Marginal bone loss after 1 year 0.9 mm NPS group, 0.6 mm PS group. No significant difference after 2, 3, 4 and 5 years
Canullo et al. [54]	RCT	25 months	22 patients/22 implants (11 NPS, 11 PS)	Global implants	Immediate	PFM with titan abutments	NPS (5 thick, 6 thin) PS (7 thick, 4 thin)	Mean bone loss 1.19 mm NPS group, 0.3 mm PS group. Tissue biotype had no influence on both groups
Hürzeler et al. [51]	Prospective	1 year	15 patients/22 implants (14 PS, 8 NPS)	3i Biomet Implant Innovations	Delayed	NR	NR	After 12 months PS group 0.12 ± 0.40 mm, NPS group 0.29 ± 0.12 mm
Prosper et al. [34]	RCT	24 months	60 patients/360 implants (180 PS, 180 NPS)	Cylindric implants & KT implants Winsix Ltd.	Delayed	NR	NR	After 12 months PS group 0.021 ± 0.11 mm, NPS group 0.101 ± 0.274 mm. After 24 months PS group 0.055 ± 0.234 mm, NPS group 0.193 ± 0.474 mm

Table IV. (*Continued*).

Study	Study type	Follow-up period	Sample size/no of implants	Type of implants	Implant placement protocol	Type of abutment/restoration	Tissue biotype	Results
Kielbassa et al. [52]	RCT	1 year	177 patients/325 implants 199 (117, 82) PS, 126 NPS	NobelActive NobelBiocare	Delayed	NR	NR	Marginal bone loss after 1 year 0.95 ± 1.37 mm PS group, 0.64 ± 0.97 mm PS group, 0.63 ± 1.18 mm NPS group. No significant difference in soft tissue changes
Fickl et al. [49]	Prospective	1 year	36 patients/89 implants (75 PS, 14 NPS)	3i Biomet	Late	NR	NR	Marginal bone loss at 1 year 0.39 ± 0.07 mm PS group, 1 ± 0.22 mm NPS group
Canullo et al. [50]	RCT	33 months	31 patients/69 implants (19 NPS, 17, 15, 18 PS in three different groups due to different platform diameters)	Global implants Sweden &Martina	Delayed	NR	NR	Mean bone loss after 21 months 1.48 mm NPS, 0.99, 0.83, 0.64 mm PS group (4.3 mm, 4.8 mm, 5.5 mm platforms with 3.8 mm abutments, respectively)
Enkling et al. [55]	RCT	1 year	25 patients/50 implants (25 PS, 25 NPS)	SIC implants	Delayed	NR	thick	Mean bone loss after 1 year 0.53 ± 0.35 mm PS group, 0.58 ± 0.55 mm NPS group
den Hartog et al. [56]	RCT	18 months	93 patients/93 implants	NobelBiocare 31 NobelPerfect 62 NobelReplace (31 rough, 31 smooth necks)	Late	31 Titanium abutments with Zirconia copings, 62 Zirconia crowns	NR	Marginal bone loss in scalloped group 2.01 ± 0.77 mm
Noelken et al. [57]	Retrospective	65.2 months	20 patients/31 implants	NobelBiocare NobelPerfect	21 immediate 7 late (3 after augmentation)	PFM crowns & Procera Zirconia	NR	Annual decrease of marginal bone level 0.14 mm from year 2 to 5. Mean average bone loss 1.6 mm after 65.2 months
Paul et al. 2013	Retrospective	5 years	26 patients/ 31 implants	NobelBiocare NobelPerfect	Immediate	PFM	NR	Mean distance between implant shoulder and bone was 2.25 ± 0.66 mm. Peri-implant soft tissue remained stable, with minimal recession

NR, not reported; NPS, non-platform-switched; PS, platform-switched.

biotype is usually associated with a flat scalloping tissue, whereas a thin biotype is usually highly scalloped. Studies reported that high scalloped tissues have a higher risk to undergo recession [69]. In contrast, flat tissue scallop tends to mimic the underlying osseous scallop, which is most commonly seen in the posterior region [38], creating more predictable maintenance of the peri-implant tissue, especially in the interproximal areas [70]. It was explained that high scalloped tissue means that there is more tissue coronal to the bone interproximally than facially. The greater the discrepancy, the higher the scallop and the higher risk for recession [71,72]. Here, it is noteworthy to mention that several other factors have been speculated to play a role in marginal bone loss, in turn, affecting the overlying soft tissue stability. An ideal three-dimensional implant placement is considered as one of the most important factors to achieve optimal function and esthetic outcome [73,74]. In addition, it has been demonstrated that the long-term stability of the peri-implant soft tissue largely depends on the presence of an adequate soft tissue volume in the vertical and the bucco-lingual directions [75]. In this context, it has been demonstrated that the gingival thickness around natural teeth does not exceed 1.3–1.5 mm in the maxilla and mandible, respectively [76]. Therefore, a biotype thickness of more than 2 mm around implants seems to be a rare condition. In addition, the presence of a thin soft tissue biotype is usually associated with an increased risk of compromised esthetics, as the dark greyish color of titanium can show through the soft tissue and lead to discoloration. For these reasons, the presence of a thin tissue biotype dictates the placement of implants in a slightly more palatal position [24]. Additionally, a supracrestal placement of implants is not recommended in such cases. Surgical trauma determined by periosteal elevation is also considered to be one of the possible etiological factors for marginal bone loss [77]. The effect of one-stage and two-stage implant surgery on peri-implant mucosa and crestal bone level changes has been evaluated in both experimental and clinical studies. Despite the large number of studies available, there are few studies which directly compare these two techniques. However, it has been reported that the mean horizontal bone loss after osseous surgery with periosteal elevation is ~0.8 mm [77]. Bone loss at the second stage surgery is generally vertical and it has been measured to be between 0.2–1.3 mm [78]. On the other hand, comparative studies showed that using one- or two-stage surgical techniques had no clinically significant effect on marginal bone loss [79,80]. Unfortunately, the signs of bone loss resulting from surgical trauma and periosteal flap elevation are not commonly observed at the second stage of implant surgery. Hence, the hypothesis of the surgical causes of peri-implant bone loss remains to be determined. However, one has to consider that the one-stage technique has less morbidity for the patients since it involves a single surgical procedure, whereas the two-stage surgery might offer greater potential for soft tissue management.

In terms of abutment material, the ability of prosthetic abutment material to form a stable peri-implant tissue can be evaluated by two parameters, namely presence or absence of bone loss and gingival recession.

A 4 year study provided clear evidence demonstrating that zirconia abutments exhibited stable marginal bone levels with healthy mucosal conditions [45]. Here, it is important to mention that, at the 4-year follow-up time point, there was an overall patient/restoration dropout of 33% leading to a limited number of samples available. On the other hand, the literature search yielded only one clinical study comparing zirconia and titanium abutments, which showed similar reaction of peri-implant hard and soft tissues to both abutments [29]. Although abutments of both titanium and alumina have demonstrated a high quality of attachment to the peri-implant mucosa, a 5 year prospective study reported that alumina seemed to show a higher degree of marginal bone loss and gingival recession in comparison to titanium [43]. In this context, it should be stressed that the included studies applied different methods to measure gingival recession and bone loss.

In regards to the esthetic outcome of peri-implant mucosa to different materials, clinical studies reported that titanium and ceramic materials induce the same degree of discoloration [41,42]. Nevertheless, one clinical study reported excellent esthetic results around titanium and alumina abutments [43]. This contradiction can be explained by the different methods used for soft tissue color assessment. Several studies measured the color of the peri-implant tissue through a spectrophotometer, whereas other studies evaluated the color of the peri-implant tissue only visually through clinician's assessment and patient's satisfaction. However, it has been reported that the thickness of the peri-implant mucosa plays an important role in the color of the marginal soft tissue around implants, regardless of the type of abutment and restoration material [22].

Although titanium is always considered the gold standard due to its excellent material stability and biological integration, it can be concluded from the limited studies included in this paper that the use of other materials such as gold and ceramic materials should not be considered as a risk factor for marginal bone loss and soft tissue recession.

Another factor that has been focused on during the search was the abutment design. Several designs have been implemented in an attempt to preserve marginal bone and soft tissue level. The literature search identified different abutment designs such as the scalloped

implants, platform switched implants [81] and the so-called gingivally converging or concave implant abutments [36,82]. All the identified studies investigated the effectiveness of these different abutment designs on preserving peri-implant marginal bone and soft tissue. No studies showing the influence of these designs on the periosteum were reported. However, the periosteal tissue is located in the vicinity of the implant abutment interface; therefore, it may play a significant role in bone regeneration around this area.

With platform-switching, the microgap will shift inwards, thus shifting the inflammatory area, which is claimed to be responsible for bone remodeling, further away from the alveolar crest, thereby reducing its damaging effect on the marginal bone [83]. However, only one long-term study (11–14 years) reported preservation of marginal bone levels around platform-switched implants [84]. This study was not included in the present review, since no control group was evaluated. Another 5 year study reported better marginal bone preservation after the first year. Even so, no differences between conventional and platform-switched implants were reported thereafter. Most of the included studies reporting less marginal bone changes around platform-switched implants were short-term studies having observation periods of no more than 3 years. Other studies identified no differences in marginal bone loss between platform-switched and standard implants [20,47,54,55,85], in which one of them reported a beneficial effect of the platform switched concept only if the implants were placed subcrestally [85]. However, some confounding factors such as the apico-coronal position of implants in relation to crestal bone, the reliability of examination methods and the degree of platform-switching should be considered when interpreting the results, as it has been reported that the degree of marginal bone resorption is inversely related to the extent of implant-abutment mismatch [50,86].

The ultimate goal of the scalloped implant design is to minimize the remodeling process seen around implants, thus improving the quality of survival by maintaining three dimensional osseous and soft tissue contours. These implants are indicated specifically for the treatment of patients exhibiting three-dimensional ridge topography [35,87,88]. The literature search revealed a limited number of studies evaluating the scalloped implant design. However, three studies were included in this paper, in which two of them reported promising results, namely stable peri-implant soft tissue and preservation of marginal bone level [57,58]. Other studies about scalloped implants reported undesirable results, which may influence the long-term esthetics and stability of the implants. These studies were not included in this review, as they did not meet the inclusion criteria [56]. However, further studies with long-term, prospective, controlled designs are needed in order to establish recommendations based on clinical evidence for use of such implants.

The gingivally converging abutments or concave abutments are implant abutments specially designed with a concave, inwardly narrowed profile at the transmucosal level, resulting in a circumferential macrogroove [36]. However, the definition of concave abutments is controversial, another study defined concave abutments as abutments being more pronounced in the buccal wall than in the palatal and interproximal walls [82]. It has been hypothesized that such design improves stabilization of the soft tissues compared to standard abutment designs. This claimed positive soft tissue behavior is hypothetically linked to the combination of three factors. First, the circumferential macrogroove creates a void chamber in which a blood clot forms that provides space for soft tissue regeneration. Second, the curved profile allows for increased length of the soft tissue-to-implant interface. Third, a ring-like seal of soft tissue is created that could stabilize the connective tissue adhesion and, to some degree, functionally mimic the effect of Sharpey's fibers attaching to teeth [36].

From the current paper, it is obvious that preservation of marginal bone and soft tissue around dental implants is multifactorial controlled by several biological and biomechanical factors. There is also a lack of evidence about the effectiveness of the available abutment designs and materials on the preservation of peri-implant marginal bone and soft tissue level, since no long-term clinical studies are available.

Conclusions

Based on the limited data available for this systematic review it is concluded that the stability of the peri-implant tissues is determined by different biological and biomechanical factors. The current paper identified several implant abutment designs implemented to achieve optimal results. No evidence was identified about the effectiveness of these designs in preventing marginal bone loss and soft tissue recession. The results of this review warrant the need for long-term clinical studies to provide evidence about this issue.

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