Effects of Platform-Switching on Peri-implant Soft and Hard Tissue Outcomes: A Systematic Review and Meta-analysis

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Purpose: *This systematic review and meta-analysis was aimed at evaluating the longitudinal effect of platform switching on implant survival rates as well as on soft and hard tissue outcomes.* ***Materials and Methods:*** *An electronic search of the databases of the National Center for Biotechnology Information, PubMed, Ovid (MEDLINE), EMBASE, Web of Science, and Cochrane Collaboration Library was conducted in February 2015. Studies published in English with at least 10 human participants and a 12-month postloading follow-up were included. Random effects meta-analyses of selected studies were applied to compare the primary and secondary outcomes of platform-switched (PS) and regular-platform (RP) implants, as well as the experimental designs and clinical outcomes.* ***Results:*** *A total of 26 studies involving 1,511 PS implants and 1,123 RP implants were evaluated. Compared to RP implants, PS implants showed a slight increase in vertical marginal bone loss (VMBL) and pocket depth reduction (weighted mean differences were –0.23 mm and –0.20 mm, respectively). The PS implants had a mean VMBL of 0.36 ± 0.15 mm within the first year of service. The meta-regression suggested a trend of decreased bone resorption at sites with thick soft tissues at baseline.* ***Conclusion:*** *This study suggested that platform switching may have an indirect protective effect on implant hard tissue outcomes.* Int J Oral Maxillofac Implants 2017;32:e9–e24. doi: 10.11607/jomi.5140

Keywords: *implant, marginal bone resorption, meta-analysis, platform switching, tissue biotype*

Preservation of peri-implant bone is a challenge in implant dentistry.[1–3] On average, approximately 1 mm of peri-implant bone loss is reported within the first year of function.[4] Thereafter, peri-implant mucosal recession, which can potentially jeopardize esthetic outcomes, may occur. In addition, the resulting exposure of implant thread(s) may aggregate plaque accumulation and lead to deterioration of peri-implant tissue health, thus affecting long-term implant stability.

The location of the implant-abutment junction, or microgap, has been considered as one of the contributing factors for peri-implant marginal bone resorption.[5,6] Lazzara and Porter proposed the concept of platform switching (PS), which involves connecting a narrower abutment to the implant to allow horizontal inward shift of the implant-abutment interface. This concept is thought to minimize peri-implant bone loss.[7]

Human histology has demonstrated that PS impedes block inflammatory infiltration and thus prevents further apical migration of peri-implant tissues.[8] In addition, PS has been shown to reduce stresses around the implant neck[9,10] by shifting the stress concentration from the compact bone to the cancellous bone and from the cervical area to the center of abutment interface.[11,12] Despite these biological and mechanical benefits, the effect of PS on soft and hard peri-implant tissues remains controversial.[13–15]

Available meta-analyses have primarily evaluated the influence of PS on marginal peri-implant bone,[16–19] thus indicating a lack of evidence on the effect of PS on peri-implant soft tissues. Therefore, this meta-analysis sets forth to investigate the effects of PS on implant survival rates and peri-implant soft and hard tissue outcomes.

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MATERIALS AND METHODS

The reporting of these meta-analyses adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement.[20] The purpose of this meta-analysis was to evaluate longitudinal influences of PS on implant survival rate as well as on hard and soft tissues outcomes. The PICO (participants, interventions, comparisons, and outcomes) format was also used for the comparison of implants with PS and those with regular platforms (RP). Hence, the focus question is: "Compared to implants with matched implant-abutment interface (C), do those with platform-switching (I) have a favorable effect on peri-implant soft tissue and hard tissue (O) in implant patients (P)?" In this study, overall PS outcomes and comparisons of PS and RP groups were both reported.

Data Sources and Search Strategies

A systematic search of the electronic databases of the National Center for Biotechnology Information, PubMed, Ovid (MEDLINE), EMBASE, Web of Science, and Cochrane Collaboration Library was conducted in February 2015. Studies published from January 2005 to January 2015 were evaluated. Search terminology was applied, potential abstracts were identified, and the full texts of these articles were obtained. Studies that fulfilled the inclusion criteria were included. The search process was performed by two independent reviewers (Y-TH and G-HL). Any disagreement between reviewers was discussed and resolved.

The search terms used, in which "mh" represented the MeSH terms and "tiab" represented the title and/or abstract, included the following: (("dental implants"[mh]) OR ("dental"[tiab] AND "implants"[tiab]) OR ("dental"[tiab] AND "implant"[tiab]) OR ("endosseous implant"[ALL] AND "dental"[tiab])) AND (("dental implant–abutment design"[ALL] OR ("dental"[tiab] AND "implant–abutment"[tiab] AND "design"[tiab]) OR ("dental implant–abutment design"[ALL]) OR (("dental"[tiab] AND "implant"[tiab] AND "platform"[tiab] AND ("switching"[tiab] OR "platform switch"[tiab] OR "platform switching"[tiab] OR "switched platform"[tiab] OR "platform switched"[tiab] OR "platform-switched"[tiab] OR "platform mismatch"[tiab] OR "platform-mismatched"[tiab] OR "platform shift"[tiab] OR "platform shifting"[tiab] OR "platform-shifted"[tiab])).

Published studies were included if they met the following inclusion criteria: *(1)* was published in English; *(2)* was a prospective clinical trial with at least 10 human subjects enrolled; *(3)* had a follow-up period of at least 12 months after implant prostheses were delivered; and *(4)* reported on the clinical outcomes of PS. In vitro studies, case reports, animal studies, retrospective studies, narrative reviews, unpublished data, communications, or expert opinions were excluded.

Quality Assessment

The quality of the selected studies was assessed using criteria modified from the CONSORT (Consolidated Standards of Reporting Trials) statements.[21] Parameters evaluated included: *(1)* appropriate population size; *(2)* definitions of inclusion and exclusion; *(3)* presence of randomization; *(4)* methods of allocation concealment; *(5)* masking of examiners; and *(6)* remarks of incomplete data. The potential risk of bias was low if all of these parameters were met. The potential risk of bias was considered to be moderate or high if the study failed to provide parameters 1 and 2, or more of these parameters, respectively. A single examiner (Y-TH) completed the quality assessment.

Data Extraction

Data extraction was performed by a single examiner (Y-TH). The data included were: *(1)* experimental design; *(2)* sample sizes of patients and implants placed; *(3)* patient demographics, such as gender and age; *(4)* smoking habit; *(5)* follow-up period after implant is in function; *(6)* flap design; *(7)* PS by implant design or implant-abutment shifting; *(8)* loading protocols; and *(9)* restoration types. The variables for outcome assessment were: *(1)* initial soft tissue thickness; *(2)* implant survival rates (ISR); *(3)* vertical marginal bone loss (VMBL); *(4)* amount of midfacial peri-implant mucosal recession (REC); *(5)* amount of peri-implant keratinized mucosa (KM); and *(6)* peri-implant probing depth (PD).

Data Analyses

The primary outcome was ISR, with VMBL, REC, and PD reduction as the secondary outcomes. The risk ratio of ISR and the pooled weighted mean difference (WMD) of VMBL, recession, and PD reduction were estimated using a computer program (RevMan Version 5.0, The Cochrane Collaboration). The contribution of each article was weighed. Random effects meta-analyses of the selected studies were applied to avoid any bias caused by methodological differences among the studies. Forest plots were produced to graphically represent the difference in outcomes of PS and RP groups for all included studies, using the implant as the unit of analysis. A P value of .05 was used as the level of significance. Heterogeneity was assessed using chi-square and I^2 tests, which ranged between 0% and 100%; lower values represented less heterogeneity. To avoid bias caused by analyzing studies with different study designs, a meta-analysis of studies using the same study design was performed as well. In addition, a funnel plot was used to assess the presence of publication bias. Regression analysis was also performed to

determine the potential effect of confounding factors, including flap/flapless techniques, PS design, and tissue biotype, on primary and secondary outcomes.

RESULTS

The initial electronic search yielded a total of 589 published articles. After the titles and abstracts of each were screened, 42 articles were selected for full-text review; of these, only 26 studies were included in the meta-analysis. The reasons for excluding 16 of the selected studies are summarized in Table 1. The intra-examiner agreement had kappa values of 93.75% and 95.83% for title/abstract and full-text review.

Features of the Included Studies

A total of 26 studies were included in this meta-analysis (Tables 2 and 3). They were 5 case series,[22–26] 5 clinical controlled trials (CCTs),[27–31] and 16 randomized controlled trials (RCTs).[32–46]

A total of 1,511 PS and 1,123 RP implants in 1,087 patients were evaluated in the selected studies (n = 26); each of the studies had follow-up periods of 12 to 168 months after loading. The median follow-up period was 19.5 months. Only six studies excluded smokers from their sample populations[34,36–40]; therefore, the majority of the studies included data on smokers.

In most of the studies, a flap was elevated during implant placement (n = 21).[22,23,26–28,30,32–41,43–47] Three of the studies used punch techniques for flapless surgery,[29,31,42] and two studies did not verify their surgical protocols.[24,25] In addition, two approaches were performed for the mismatching: 12 of the studies placed implants with PS design[22,23,25,26,29,31,33,34,36,37,40,45] and 14 of the studies connected narrower abutments onto the implants.[24,27,28,30,32,35,38,39,41–44,46,47]

Based on the loading protocols defined by the 4th International Team for Implantology (ITI) Consensus Conference,[48] implants in 17 of the studies were restored after a healing period of 2 months (conventional loading).[22,24,27,28,30–38,40,41,43,45] Seven studies used immediate loading protocols[23,25,26,29,42,44,47] and two studies failed to provide their loading protocols.[39,46] All implants were restored with fixed prostheses, such as screw-retained (n = 2),[25,30] cement-retained (n = 19),[22,23,26,27,29,32–44,47] or unspecified (n = 5)[24,28,31,45,46] implant prostheses.

Results of the Meta-analyses

A total of 15 studies[26,27,29–34,36,37,39,40,42,43,46] showed a mean VMBL of 0.36 ± 0.15 mm within the first year of service. The peri-implant crestal bone level remained consistent, since the VMBL were 0.50 ± 0.21 mm,[25,28,29,35,38,43,45] 0.44 ± 0.16 mm,[22,30,33,35,43,44,47] 0.60 ± 0.20 mm,[30,33] and 0.47 ± 0.26 mm[24,30] at 1 to 2 years, 2 to 3 years, 3 to 4 years, and more than 5 years of function, respectively. On the other hand, all of the included studies reported marginal changes in peri-implant soft tissue outcomes around PS implants, which were 0.41 ± 0.35 mm of increased PD,[26,32,34,36,37,40,42] 0.40 ± 0.42 mm of REC,[38,42,47] and 0.44 ± 0.33 mm of KM loss.[26,42]

A total of 5 CCTs[27–31] and 16 RCTs[32–47] reported data on ISR of implants with PS and RP designs. Meta-analysis for the comparison of ISR among selected studies presented an overall risk ratio of 1.00 (95% confidence interval [CI] = 0.99 to 1.01 mm) with no statistical significance ($P = .64$) (Fig 1). For CCTs, the risk ratio of ISR between implants of PS design and RP design was 1.00 (95% CI = 0.99 to 1.01 mm; $P = .87$). For RCTs, the risk ratio of ISR was 1.01 (95% CI = 0.99 to 1.02 mm; $P = .39$). The comparisons revealed low heterogeneity

Table 1 Summary of Excluded Articles

References	Reason for exclusion
Guirado et al (2007)	Follow-up period < 12 months after service
Trammell et al (2009)	Numbers of implants in both groups not provided
Canullo et al (2010)	Part of project published in another paper (Canullo et al [2010] COIR); primary outcome was microbial results
Linkevicius et al (2010)	Experimental population < 10 patients
Donovan et al (2010)	Retrospective experimental design
Bilhan et al (2010)	Retrospective experimental design
de Almeida et al (2011)	Retrospective experimental design
Enkling et al (2011)	Follow-up period < 12 months after service
Canullo et al (2011) JOMI	Experimental population < 10 patients
Vandeweghe et al (2012)	Follow-up period < 12 months after service
Dursun et al 2012	Follow-up period < 12 months after service
Canullo et al (2012)	Clinical outcomes not presented
Collins et al (2013)	Follow-up period < 12 months after service
Heinemann et al (2013)	Failed to report standard deviation
Meloni et al (2014)	Follow-up period < 12 months after service
Wang et al (2015)	Follow-up period < 12 months after service

Table 2 Features of Included Articles

Authors	Design	Participants			Implants in RP group	Implants in PS group
		N	Mean years of age (SD) and gender	Smokers included		
Wagenberg and Froum (2010)[24]	Case series	78	n/a	Y	n/a	78 / 106
Cocchetto et al (2010)[22]	Case series	10	n/a	n/a	n/a	10 / 15
Romanos and Nentwig (2009)[23]	Case series	15	54.8 (5.7) 5F / 10M	Y	n/a	15 / 90
Calvo-Guirado et al (2009)[26]	Case series	50	39.6 (6.1) 25F / 25M	Y	n/a	50 / 61
Calvo-Guirado et al (2008)[25]	Case series	18	56.0 (7.3) 15F / 3M	Y	n/a	18 / 105
Veis et al (2010)[28]	CCT	n/a	n/a	n/a	193	89
Fickl et al (2010)[27]	CCT	36	55.3 (–) 18F / 18M	n/a	14	75
Vigolo and Givani (2009)[30]	CCT	144	37 (–)	n/a	85	97
Crespi et al (2009)[29]	CCT	45	48.73 (–) 27F / 18M	Y	34	30
Cappiello et al (2008)[31]	CCT	45	n/a	n/a	56	75
Telleman et al (2014)[34]	RCT	17	53.7 (11.7) 17F / 0M	N	29	29
Pozzi et al (2014)[33]	RCT	34	52.20 (5.34) 19F / 15M	Y	44	44
Guerra et al (2014)[32]	RCT	68	51.41 (12.58) 31F / 37M	Y	72	72
Telleman et al (2013)[37]	RCT	92	50.6 (11.7) 77F / 15M	N	76	73
Enkling et al (2013)[35]	RCT	25	51 (10.5) 10F / 5M	n/a	25	25
Gultekin et al (2013)[36]	RCT	25	41.3 (–) 20F / 5M	N	50	43
Canullo et al (2012)[38]	RCT	40	58.2 (–) 16F / 34M	N	40	40
Telleman et al (2012)[40]	RCT	80	49.8 (12.2) 53F / 27M	N	59	54
Fernández-Formoso et al (2012)[39]	RCT	51	43.29 (–) 33F / 18M	N	56	58
Pieri et al (2011)[42]	RCT	40	46.2 (–) 25F / 15M	Y	20	20
Canullo et al (2011)[41]	RCT	14	n/a	Y	11	26
Canullo et al (2010)[43]	RCT	31	52.1 (–) 14F / 17M	Y	19	50
Canullo et al (2009)[44]	RCT	22	50 (14.46) 9F / 13M	Y	11	11
Canullo et al (2009)[47]	RCT	60	53.9 (6.8) 28F / 32M	Y	240	120
Prosper et al (2009)[45]	RCT	15	55.3 (–) 8F / 7M	n/a	8	14
Hürzeler et al (2007)[46]	RCT	22	50 (14.46) 9F / 13M	Y	11	

RP = regular platform/platform-matching; PS = platform-switching; CCT = clinical controlled trail; RCT = randomized clinical trial; n/a = not applicable.

Implant/prosthetic designs				
Follow-up period after service (mo)	Flap design	PS by implant design/ implant-abutment shifting	Loading protocols	Restoration types
132–168	n/a	Implant-abutment shifting	Immediate and delayed	n/a
18	Flapped	Implant design	Conventional	Cemented
42.4 (19.1)	Flapped	Implant design	Immediate	Cemented
12	Flapped	Implant design	Immediate	Cemented
16	n/a	Implant design	Immediate	Screw
24	Flapped	Implant-abutment shifting	Conventional	n/a
12	Flapped	Implant-abutment shifting	Conventional	Cemented
60	Flapped	Implant-abutment shifting	Conventional	Screw
24	Flapless	Implant design	Immediate	Cemented
12	Flapless	Implant design	Conventional	n/a
12	Flapped	Implant design	Conventional	Cemented
40	Flapped	Implant design	Conventional	Cemented
12	Flapped	Implant-abutment shifting	Early/conventional	Cemented
12	Flapped	Implant design	Conventional	Cemented
34	Flapped	Implant-abutment shifting	Conventional	Cemented
12	Flapped	Implant design	Conventional	Cemented
18	Flapped	Implant-abutment shifting	Conventional	Cemented
12	Flapped	Implant design	Conventional	Cemented
12	Flapped	Implant-abutment shifting	n/a	Cemented
12	Flapless	Implant-abutment shifting	Immediate	Cemented
48	Flapped	Implant-abutment shifting	Conventional	Cemented
30	Flapped	Implant-abutment shifting	Conventional	Cemented
25	Flapped	Implant-abutment shifting	Immediate	Cemented
24	Flapped	Implant-abutment shifting	Immediate	Cemented
21M for mandible; 18M for maxilla	Flapped	Implant design	Conventional	n/a
25	Flapped	Implant-abutment shifting	n/a	n/a

Table 3 Treatment Outcomes of Included Articles

		Outcomes (RP/PS)		
Authors	Initial tissue thickness	ISR (%)	ΔVMBL (mm)	Midfacial soft tissue height (mm)
Wagenberg and Froum (2010)[24]	n/a	89.62	PS Mesial: 0.34 (0.67) Distal: 0.33 (0.63)	n/a
Cocchetto et al (2010)[22]	n/a	100	PS 0.30 (0.37)	n/a
Romanos and Nentwig (2009)[23]	n/a	96.66	PS After 42.4M in service, 77 sites with no bone loss; 10 sites with 0 to 2 mm bone loss	
Calvo-Guirado et al (2009)[26]	n/a	96.70	PS Mesial BL: 3.57 (1.1); follow-up: 3.65 (1.5) Distal BL: 3.49 (0.8); follow-up: 3.58 (0.7)	n/a
Calvo-Guirado et al (2008)[25]	n/a	99.1	PS BL: –0.5 (0.8); 12M: +0.6 (1.0); 16M: +0.6 (1.0)	n/a
Veis et al (2010)[28]	n/a	100/100	0.88 (0.85)/0.75 (0.55)	n/a
Fickl et al (2010)[27]	n/a	100/100	0.23 (0.18)/0.10 (0.05)	n/a
Vigolo and Givani (2009)[30]	n/a	100/100	RP 1Y: 0.9 (0.3); 2Y: 1.0 (0.3); 3Y: 1.0 (0.3); 4Y: 1.1 (0.3); 5Y: 1.1 (0.3) PS 1Y: 0.6(0.2); 2Y: 0.6 (0.2); 3Y: 0.6 (0.2); 4Y: 0.6 (0.2); 5Y: 0.6 (0.2)	n/a
Crespi et al (2009)[29]	n/a	100/100	RP BL: 0.99 (0.38); 12M: 0.82 (0.40); 24M: 0.78 (0.45) PS BL: 0.98 (0.34); 12M: 0.78 (0.49); 24M: 0.73 (0.52)	n/a
Cappiello et al (2008)[31]	n/a	100/98.3	1.78 (0.26) /1.05 (0.22)	n/a
Telleman et al (2014)[34]	n/a	93.6/93.6	0.85 (0.65)/0.53 (0.54)	n/a
Pozzi et al (2014)[33]	n/a	100/100	RP BL: 0.05 (0.30); 1Y: 1.15 (0.34); 3Y: 1.29 (0.42) PS BL: 0.16 (0.28); 1Y: 0.68 (0.34); 3Y: 0.83 (0.27)	n/a
Guerra et al (2014)[32]	n/a	100/97.3	RP BL: 0.66 (0.70); follow-up: 0.69 (0.68) PS BL: 0.50 (0.42); follow-up: 0.40 (0.46)	n/a
Telleman et al (2013)[37]	0.87/1.697	92.1/95.9	0.74 (0.61)/0.50 (0.53)	n/a
Enkling et al (2013)[35]	Medium-thick	100/100	RP BL: 0.38 (0.43); 21M: 0.63 (0.57); 34M: 0.74 (0.57) PS BL: 0.30 (0.52); 21M: 0.56 (0.35); 34M: 0.69 (0.43)	n/a

KM width (mm)	ΔPPD (mm)	Main conclusion
n/a	n/a	PS concept preserves crestal bone levels
n/a	n/a	When properly selected, patients receiving wide PS implants may experience less crestal bone loss than with regular platform switching or traditional non-PS approaches
PS BL: 4.26 (1.72) 42.4M follow-up: 3.44 (1.78)	PS Buccal BL: 1.83 (0.6); follow-up: 2.58 (1.17) Mesial BL: 2.14 (0.84); follow-up: 2.73 (0.86)	Immediate loading protocol in maxilla can be successful when implant primary stability, cross-arch stabilization, and soft diet for initial stages of healing are considered
BL: 3.4 (0.6) follow-up: 3.1 (0.5)	Buccal: 3.0 (0.8) Lingual: 3.4 (1.2) Proximal: 3.7 (0.87)	Implants remained stable for 12 months and had overall survival rate of 96.7%; minimal crestal bone loss recorded around the surviving implants
n/a	n/a	Immediate loading on IOL Diem abutments is a reliable and effective technique for edentulous patients in the maxilla and mandible
n/a	n/a	PS concept beneficial only in subcrestal locations, not during overall sample comparison
n/a	n/a	PS seems to limit crestal bone remodeling to a certain extent
n/a	n/a	The 85 implants restored with matching wide-diameter prosthetic components showed more bone loss than the 97 implants restored with PS prosthetic components
n/a	n/a	No differences found in bone level changes between PS and conventional external-hexagon implants
n/a	n/a	PS seems to reduce peri-implant crestal bone resorption and increase long-term predictability of implant therapy
n/a	1 imp: –0.06 (0.85)/–0.44 (1.00) > 2 imp: –0.19 (0.72)/–0.36 (0.61)	Peri-implant bone remodeling affected by platform switching; one year after loading, interproximal bone levels were better maintained at implants restored with PD concept
n/a	n/a	Both horizontal and vertical marginal bone loss had statistically lower significance in PS versus RP implants
n/a	RP BL: 1.69 (0.51); follow-up: 2.46 (0.51) PS BL: 1.78 (0.79); follow-up: 2.21 (0.47)	Positive impact in maintenance of or even enhancement of crestal bone levels when compared with platform-matching abutments of same implant system
n/a	1 imp: –0.10 (1.17)/–0.09 (0.66) > 2 imp: –0.24 (0.62)/–0.28 (0.60)	Short implants with a platform-switched implant-abutment connection showed significantly less peri-implant bone loss after 1 year in function
n/a	n/a	Limited vertical bone loss was observed regardless of whether a PS or a standard-platform concept was used

Table 3 *continued* Treatment Outcomes of Included Articles

Authors	Initial tissue thickness	Outcomes (RP/PS) ISR (%)	ΔVMBL (mm)	Midfacial soft tissue height (mm)
Gultekin et al (2013)[36]	n/a	100/100	0.83 (0.16)/0.35 (0.13)	n/a
Canullo et al (2012)[38]	n/a	100/100	1.6 (0.3)/0.5 (0.1)	0.6/2.4
Telleman et al (2012)[40]	1.08/2.35	93.1/94.5	0.73 (0.48)/0.51 (0.51)	n/a
Fernández-Formoso et al (2012)[39]	n/a	100/100	RP BL: 1.81 (0.18); follow-up: 2.23 (0.22) PS BL: 0.72 (0.85); follow-up: 0.68 (0.88)	
Pieri et al (2011)[42]	1.57 (0.41)/ 1.69 (0.42)	100/94.7	0.49 (0.25)/0.19 (0.17)	0.73 (0.52)/ −0.61 (0.54)
Canullo et al (2011)[41]	n/a	100/100	n/a	n/a
Canullo et al (2010)[43]	n/a	100/100	RP BL: 1.23 (0.67); 12M: 1.46 (0.53); 18M: 1.49 (0.54); 30M: 1.48 (0.42) PS1 (mis- 0.25 mm) BL: 0.74 (0.39); 12M: 0.95 (0.35); 18M: 0.99 (0.42); 30M: 0.99 (0.42) PS2 (mis- 0.5 mm) BL: 0.64 (0.40); 12M: 0.78 (0.35); 18M: 0.82 (0.36); 30M: 0.87 (0.43) PS3 (mis- 0.85 mm) BL: 0.41 (0.28); 12M: 0.51 (0.29); 18M: 0.56 (0.31); 30M: 0.64 (0.32)	n/a
Canullo et al (2009)[44]	11× thick biotype	100/100	n/a	−0.45 (0.27)/ 0.18 (0.46)
Canullo et al (2009)[47]	11× thick biotype	100/100	1.19 (0.384)/0.3 (0.157)	n/a
Prosper et al (2009)[45]	n/a	96.7/100	RP1 (submerged, enlarged platform): 0 RP2 (nonsubmerged, enlarged platform): 0.055 (0.234) RP3 (submerged, with standard platform): 0.275 (0.467) RP4 (nonsubmerged, with standard platform): 0.193 (0.474) PS1 (submerged, enlarged platform): 0 PS2 (submerged PS with standard platform): 0.101 (0.274)	n/a
Hürzeler et al (2007)[46]	n/a	100/100	0.29 (0.34)/0.12 (0.4)	n/a

RP = regular platform/platform-matching; PS = platform-switching; ISR = implant survival rate; ΔVMBL = changes of vertical marginal bone loss;

levels among the selected studies (*P* values for chi-square analyses = .99 and .98, and I^2 test = 0% and 0%, for CCTs and RCTs, respectively). The combined effect for all subgroups also showed low heterogeneity levels among the selected studies (*P* value for chi-square analysis = 1.00 and I^2 test = 0%).

Data on VMBL of implants with PS and RP designs were reported in 5 CCTs[27–31] and 14 RCTs.[32–40,42–46] The statistical results from each of the selected studies were converted into effect sizes and combined in the meta-analysis. None of the comparisons for VMBL showed statistical significance when the pooled results

KM width (mm)	ΔPPD (mm)	Main conclusion
n/a	C- BL: 2.58 (0.61) follow-up: 3.33 (0.51) T- BL: 2.60 (0.46) follow-up: 2.96 (0.45)	12 months after functional loading, test implants demonstrated significantly less bone resorption than control implants
n/a	n/a	Decreased bone loss observed around platform-switched implants compared to traditional external hexagon implants
n/a	1 imp: –0.22 (1.09)/–0.02 (0.57) > 2 imp: 0.18 (0.50)/–0.71 (0.55)	Crestal bone resorption may be reduced by PS
		PS design could preserve the crestal bone level up to 1-year follow-up
RP BL: 3.92 (0.78); follow-up: 3.84 (0.57) PS BL: 4.05 (0.72); follow-up: 3.86 (0.72)	RP BL: 3.5 (0.63); follow-up: 2.71 (0.48) PS BL: 3.34 (0.7); follow-up: 2.58 (0.49)	Although control group demonstrated slight increase in marginal bone loss compared to test group, peri-implant soft tissue was very stable with both types of implant-abutment connections after 12 months of loading
n/a	RP: 3 (0) PS1 (mis- 0.5 mm): 2.4 (0.6) PS2 (mis- 1.0 mm): 2.5 (0.7) PS3 (mis- 1.7 mm): 3 (0)	48 months after restoration, the peri-implant soft tissue around test and control sites had similar histological characteristics
n/a	n/a	Marginal bone levels better maintained at implants restored according to the PS concept
n/a	n/a	Marginal bone levels better maintained with implants restored according to the PS concept
n/a	n/a	Immediately placed implants with subsequent platform switching can provide peri-implant tissue stability
n/a	n/a	Immediate single-implant restorations in specific maxillary sites with subsequent platform switching may provide peri-implant alveolar bone-level stability
n/a	n/a	Positive effect of PS concept stronger when implemented on implants with enlarged platforms

KM width = changes of keratinized mucosa width; ΔPPD = changes of peri-implant probing depth; n/a = not applicable.

of CCTs and RCTs were examined (Fig 2). For CCTs, the WMD was –0.13 mm (95% CI = –0.55 to 0.30 mm; P = .56). For RCTs, the WMD was –0.27 mm (95% CI = –0.55 to 0.01 mm; P = .06). Interestingly, for combined analysis, the WMD was –0.23 mm (95% CI = –0.46 to 0.00 mm; P = .05), and this marginal statistical significance favored the PS group. However, all comparisons revealed considerable heterogeneity among studies. Chi-square analysis of all of the CCTs, RCTs, and associated combinations showed statistical significance (P < .0001 and I^2 test = 99%).

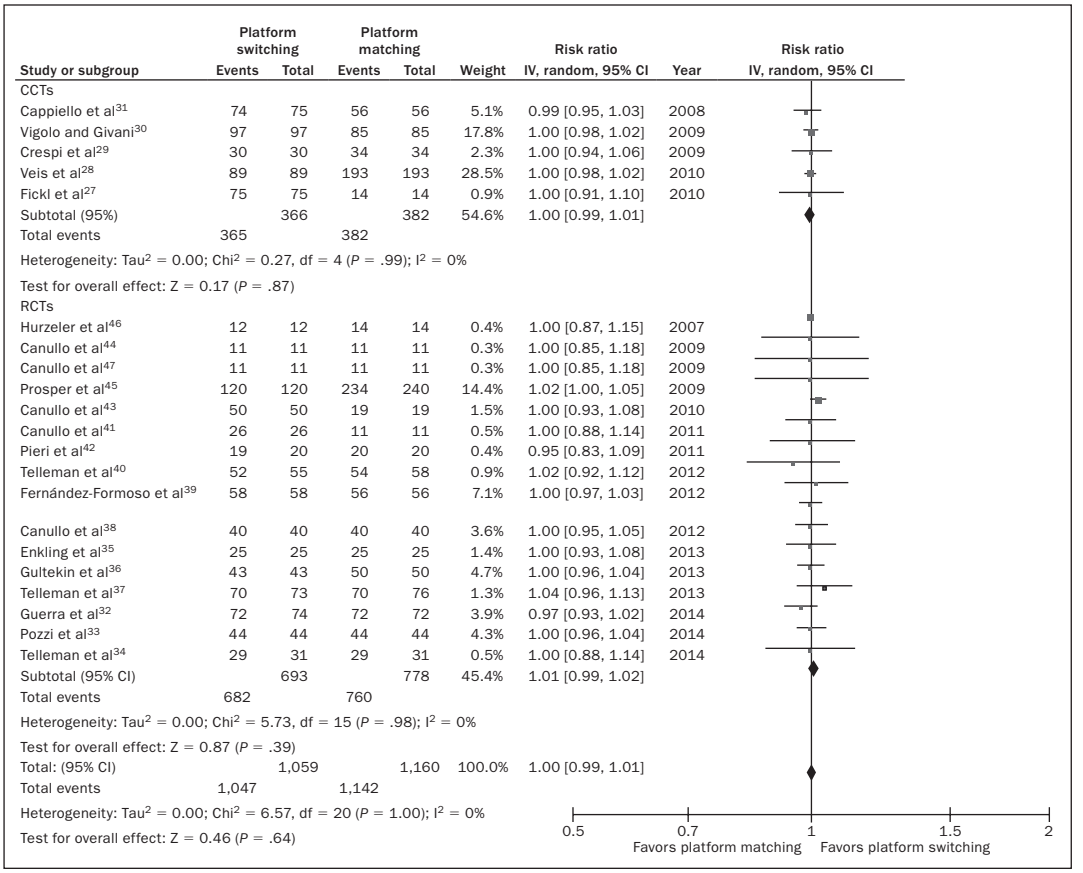

Fig 1 Meta-analysis for the comparison of implant survival rates among the selected studies.

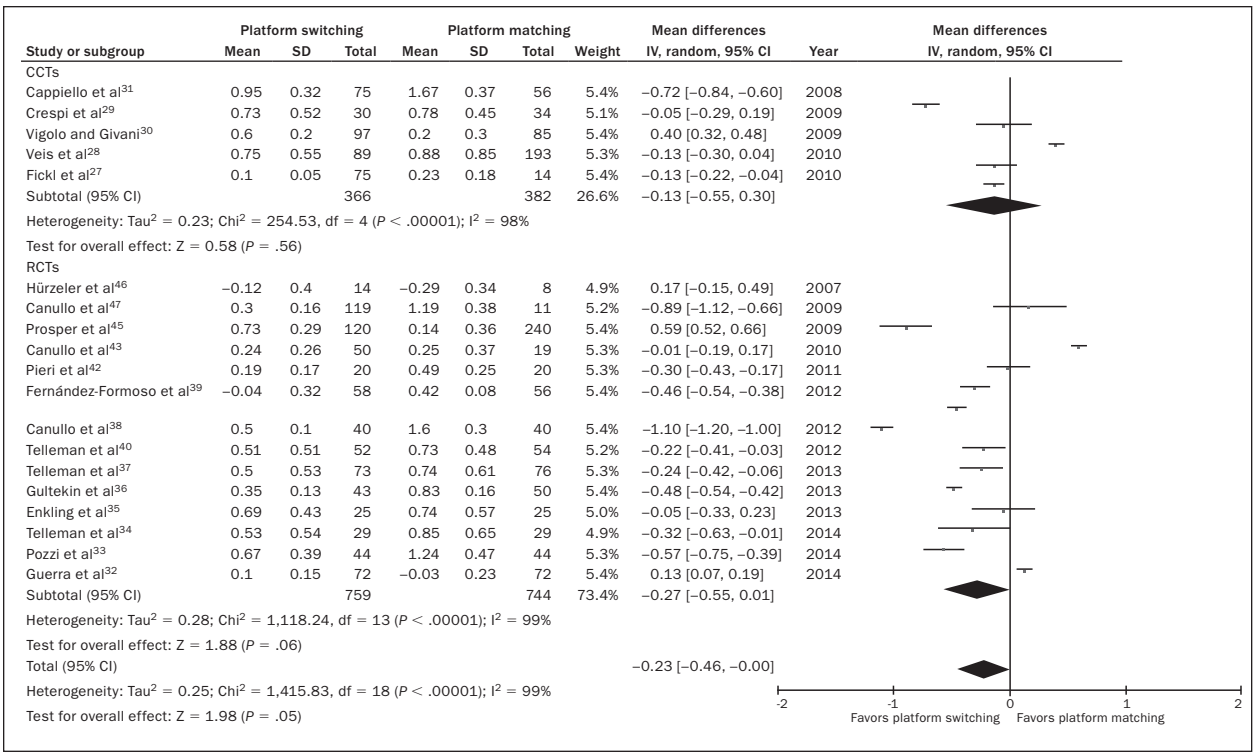

Fig 2 Meta-analysis for the comparison of vertical marginal bone loss among the selected studies.

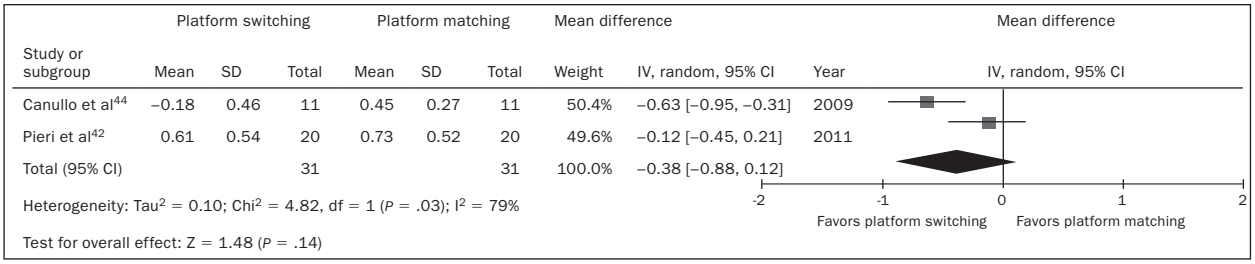

Fig 3 Meta-analysis for the comparison of the amount of recession between the selected studies.

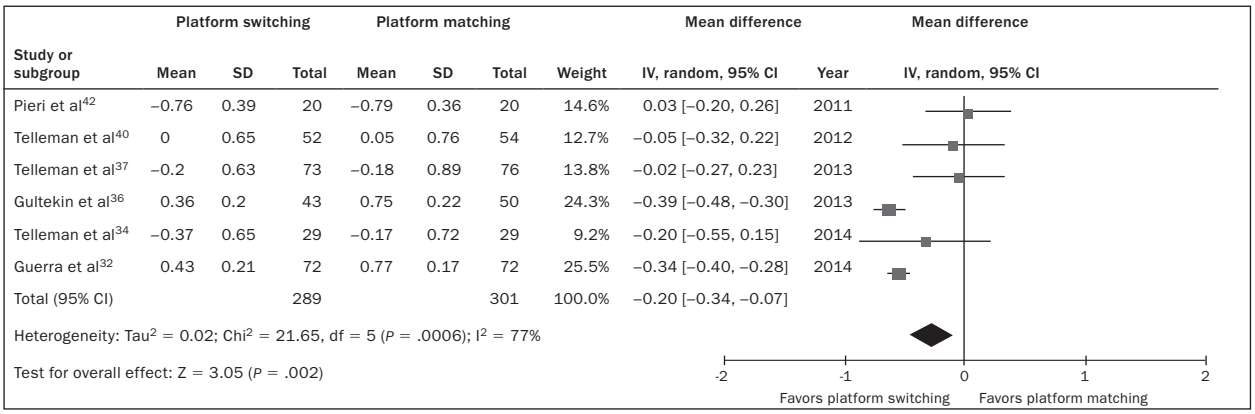

Fig 4 Meta-analysis for the comparison of the amount of pocket depth reduction among selected studies.

The amount of recession around implants with PS and RP designs was reported in two RCTs.[42,47] The WMD was –0.38 mm (95% CI = –0.88 to 0.12 mm; P = .14) (Fig 3). High levels of heterogeneity were detected among the studies (P value for chi-square analysis = .03 and I^2 test = 79%).

The amount of PD reduction of implants with PS and RP designs was reported in six RCTs.[32,34,36,37,40,42] The WMD was –0.20 mm (95% CI = –0.34 to –0.07 mm; P = .002) (Fig 4), favoring the PS design. The meta-analysis of PD reduction showed high heterogeneity levels among the studies (P value for chi-square analysis < .0001 and I^2 test = 77%).

Results of Meta-regression

The meta-regression was used to analyze three confounding factors: *(1)* flap/flapless techniques, *(2)* PS by implant design or implant-abutment shifting, and *(3)* initial tissue thickness. For ISR and VMBL, the three confounding factors did not significantly influence the outcome in any subgroup or overall analysis. Nonetheless, it is worth noting that the thick tissue biotype had less marginal bone resorption than the thin tissue biotype; however, the difference marginally approached statistical significance (P = .09).

Risk of Bias Assessment

Table 4 summarizes the quality assessment of all included articles. All of the case series were categorized as having a high risk of bias.[22–26] Of the 5 CCTs and 16 RCTs included in this meta-analysis, only 4 studies showed a low risk of bias.[32,35,44,47] The rest of the studies were considered to have a moderate[29,30,33,34,36,38–40,42] or high risk of bias[27,28,31,37,41,43,45,46] (9 studies each). Therefore, the results of data pooled from studies exhibiting high experimental heterogeneity should be interpreted with caution. To investigate potential publication bias, the funnel plots of meta-analyses for comparisons of ISR and VMBL are demonstrated in Figs 5 (ISR), 6 (VMBL), 7 (recession), and 8 (PD reduction).

DISCUSSION

This systematic review and meta-analysis of 26 selected studies showed that PS implants had a high ISR as well as stable hard and soft tissue outcomes. Following implant loading, crestal bone level change around PS implants was 0.36 ± 0.15 mm within the first year and remained less than 0.5 mm after 5 years of service. Slight loss of midfacial soft tissue height and

Table 4 Summary of Quality Assessment

Authors	Author (year)	Representative population group	Defined inclusion/ exclusion	Randomization methods	Allocation concealment method	Examiner masked	Intervention different only	All patients accounted for at end of study	Estimated potential risk of bias*
Wagenberg and Froum (2010)[24]	Y	Y	Case series	n/a	Y	n/a	Y	Y	High
Cocchetto et al (2010)[22]	Y	Y	Case series	n/a	?	n/a	Y	Y	High
Romanos and Nentwig (2009)[23]	Y	Y	Case series	n/a	Y	n/a	Y	Y	High
Calvo-Guirado et al (2009)[26]	Y	Y	Case series	n/a	?	n/a	N	Y	High
Calvo-Guirado et al (2008)[25]	Y	Y	Case series	n/a	?	n/a	N	Y	High
Veis et al (2010)[28]	Y	Y	CCT	n/a	?	N	?	N	High
Fickl et al (2010)[27]	Y	Y	CCT	n/a	?	Y	Y	Y	High
Vigolo and Givani (2009)[30]	Y	Y	CCT	n/a	Y	Y	Y	Y	Moderate
Crespi et al (2009)[29]	Y	Y	CCT	n/a	Y	Y	Y	Y	Moderate
Cappiello et al (2008)[31]	Y	Y	CCT	n/a	?	Y	N	Y	High
Telleman et al (2014)[34]	Y	Y	RCT	Y	?	Y	Y	Y	Moderate
Pozzi et al (2014)[33]	Y	Y	RCT	?	Y	Y	Y	Y	Moderate
Guerra et al (2014)[32]	Y	Y	RCT	Y	Y	Y	Y	Y	Low
Telleman et al (2013)[37]	Y	Y	RCT	Y	?	Y	N	N	High
Enkling et al (2013)[35]	Y	Y	RCT	Y	Y	Y	Y	Y	Low
Gultekin et al (2013)[36]	Y	Y	RCT	Y	?	Y	Y	Y	Moderate
Canullo et al (2012)[38]	Y	Y	RCT	?	Y	Y	Y	Y	Moderate
Telleman et al (2012)[40]	Y	Y	RCT	Y	?	Y	Y	Y	Moderate
Fernández-Formoso et al (2012)[39]	Y	Y	RCT	Y	?	Y	Y	Y	Moderate
Pieri et al (2011)[42]	Y	Y	RCT	Y	Y	Y	N	Y	Moderate
Canullo et al (2011)[41]	Y	Y	RCT	Y	?	Y	N	N	High
Canullo et al (2010)[43]	Y	Y	RCT	Y	Y	Y	N	N	High
Canullo et al (2009)[44]	Y	Y	RCT	Y	Y	Y	Y	Y	Low
Canullo et al (2009)[47]	Y	Y	RCT	Y	Y	Y	Y	Y	Low
Prosper et al (2009)[45]	Y	Y	RCT	Y	Y	N	N	Y	High
Hürzeler et al (2007)[46]	Y	Y	RCT	?	?	Y	Y	Y	High

CCT = clinical controlled trail; RCT = randomized clinical trial; n/a = not applicable.
*Regarding the evaluation of the risk potential for bias, both "?" and "No" count as "No" and the responses "Yes" and "n/a" count as "Yes." Articles with all "Yes" responses are low risk, articles with one "No" response are moderate risk, and articles with two or more "No" responses are high risk.

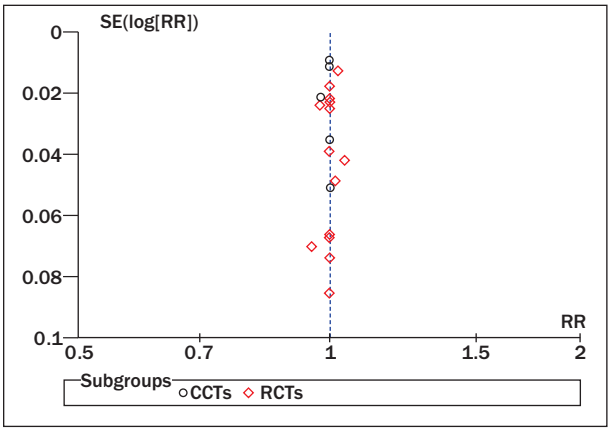

Fig 5 Funnel plot of meta-analysis of implant survival rates among the selected studies.

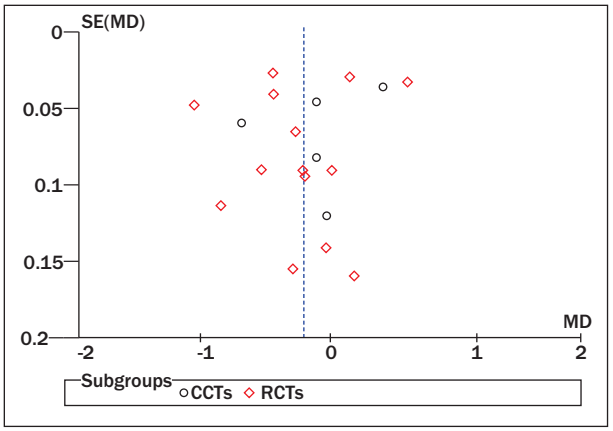

Fig 6 Funnel plot of meta-analysis of vertical marginal bone loss among the selected studies. SE = standard error; MD = mean differences.

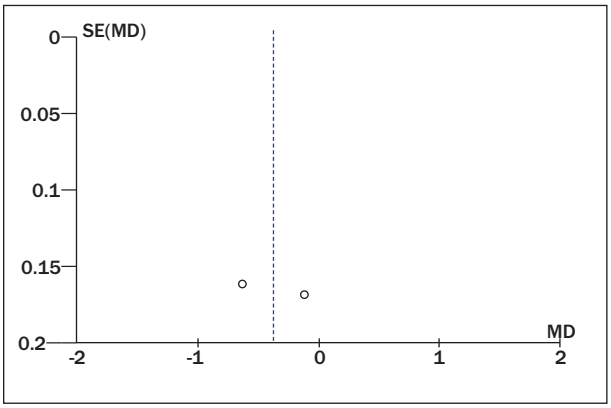

Fig 7 Funnel plot of meta-analysis of the amount of recession among the selected studies.

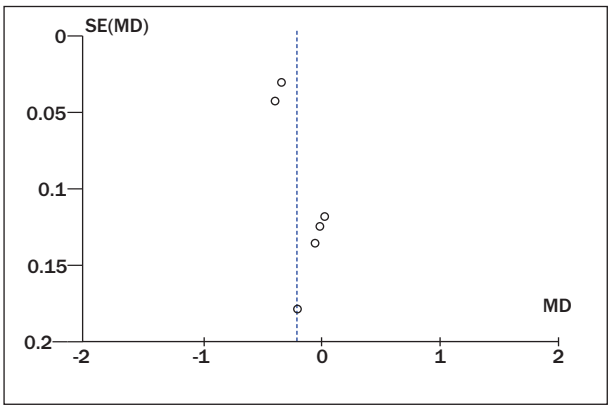

Fig 8 Funnel plot of meta-analysis of the amount of pocket depth reduction among the selected studies.

peri-implant KM were also found around PS implants. Compared to RP (eg, matched-platform) implants, equivalent and slightly better ISRs were found with PS implants. PS implants had lower VMBL (0.23 mm) and greater PD reduction (0.20 mm) compared to RP implants. To the authors' knowledge, this is the first meta-analysis that evaluates the effect of PS on both hard and soft tissue outcomes.

The results of this meta-analysis reported minimal amounts of marginal bone resorption following the first year of function and steady crestal bone levels thereafter. Changes in crestal bone level were marginally lower in the PS group compared to the RP group. In addition, VMBL was also lower in the PS group, thereby supporting the protective effect of PS.

In the selected studies, it was found that different implant neck designs did not significantly influence clinical outcomes.[35] However, apicocoronal positions of implant placement (eg, supracrestal, crestal, or subcrestal) seemed to affect VMBL.

It has been suggested that PS minimizes VMBL around subcrestally placed implants. In a clinical trial, implants placed subcrestally had significantly more VMBL in the RP group (0.81 ± 0.79 mm) compared to the PS group (0.39 ± 0.52 mm).[28] In addition, the WMDs of VMBL for CCTs and RCTs in this meta-analysis were –0.13 and –0.27 mm, respectively, with only three studies showing > 1 mm of intergroup differences in VMBL.[31,38,39] All of these changes occurred within 18 months following crown placement. In other words, the effect of PS on marginal bone level changes appeared to be limited to the early stage of crestal bone remodeling.

After more than 1 year of function, slight soft tissue loss was observed in PS implants with regard to peri-implant PD, REC, and KM loss. Therefore, it appeared that the effect of PS on soft tissue parameters was less significant than its effect on VMBL. Despite the relationship between crestal bone level and soft tissue parameters,[49,50] other factors, such as tissue biotype and probing reliability, may also influence soft tissue outcomes. In a study evaluating facial gingival tissue stability over a mean experimental period of 4 years, it was found that the group with thin tissue biotype

(–1.50 ± 0.88 mm) had significantly greater soft tissue loss than the group with thick tissue biotype (–0.56 ± 0.46 mm).[51] In addition, the degree of disease severity and probing force may influence PD measurements.[52,53] Hence, the results of soft tissue outcomes in the present study should be interpreted with caution, since these soft tissue measurements were reported randomly in a few of the studies,[23,26,32,34,36,37,40,42] with high heterogeneity among the studies.

Although without statistically significant difference, the meta-regression showed a trend of marginal bone preservation at sites with thick tissue biotype. This finding confirmed the theory that greater bone loss occurs in groups with thin initial tissue thickness (2 mm or less).[54,55] In patients with PS implants, the authors found that crestal bone changes at 1-year follow-up were 1.17 mm and 0.21 mm in thin and thick groups, respectively. Hence, it was suggested that thick initial gingival tissue, rather than the PS design, may play a key role in preventing marginal bone loss.[56] The present meta-analysis found that six studies mentioned the patients' initial tissue thickness.[35,37,40,42,44,47] However, none of them reported data regarding an association between tissue thickness and VMBL. Therefore, it is difficult to further evaluate the impact of thick tissue on marginal bone preservation in conjunction with the platform-switching concept. On the other hand, data from this study suggest that flapless techniques and implant abutment designs may not contribute to reduction of bone resorption. Therefore, additional benefits of flapless surgery and implant PS designs on marginal bone preservation remain to be determined. Implants placed via flapless and flapped approaches with RP implants were found to have comparable marginal bone resorption levels.[57] To date, limited data are available for these comparisons with PS implants. Further studies are necessary to verify the roles of implant PS designs and surgical techniques on marginal bone preservation.

Limitations of this meta-analysis include experimental heterogeneity, estimated potential risks of bias, and the small number of studies that reported soft tissue outcomes. In addition to the three confounding factors investigated in the meta-regression, multiple factors in experimental designs, such as prosthesis types, implant locations, and smoking status, may also influence soft and hard tissue outcomes. The impact of these factors was not evaluated, since the data cannot be extracted for further analysis. For instance, all of the included studies failed to report separate outcomes on current smokers, former smokers, and nonsmokers. Grafting was mentioned in the studies, but the details—materials, location, and individual outcomes—were not disclosed. In addition, some of the existing studies came from the same research group, which may result in potential bias in the data analysis. Compared with marginal bone changes, relatively few of the studies reported on soft tissue outcomes. Due to the paucity of available information, this meta-analysis did not review the outcomes of implant complications, histologic assessments, peri-implant microbial profiles, and patient satisfaction. These topics should be investigated in future studies for further assessment of the effects of PS design.

CONCLUSIONS

Within the limitations of this systematic review and meta-analysis, the following conclusions can be drawn: Implants with a platform-switching design may provide a slight but significant protective effect on hard tissue outcomes when compared to regular matched implant restorations. Stable soft tissue outcomes have been shown around platform-switching implants. Additional benefits from flapless surgery and platform-switching implant designs may be questioned regarding bone preservation. In the meta-regression, the thick tissue biotype appears to be crucial to the reduction of crestal bone remodeling.

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