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The mechanical complications of platform switching connection of implant-supported restorations: A systematic review and meta-analysis

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KEY WORDS: Implant platform switching; Implant-abutment mismatch; Dental abutment; Mechanical complications.

ABSTRACT

Aim Platform implant abutment connection proved success in preserving crestal bone around implants, but the increased stress concentration on the prosthetic components is still a question. The primary aim of this systematic review was to evaluate the available evidence on the mechanical effect of implant platform switching concept on implant prosthetic components.

Methods A protocol of electronic and hand research was performed for English based researches comparing one or more PS groups with one or more PM groups to develop an answer for the following question: "Will the platform switching technique affect the amount of stresses generated within implant prosthetic components causing mechanical complications? A meta-analysis was performed to evaluate the impact of implant-abutment platform mismatch on implant prosthetic components.

Results Eleven publications from twenty research studies were included. Results from the meta-analysis demonstrated the odds of survival in the Platform matching connection arm are 2.13 times more compared to the Platform switching arm. (P-value= 0.0316) For the random effects model, the odds of survival in the PS arm is not statistically significantly different compared to the PM arm (p-value= 0.2224) due to substantial heterogeneity of the included studies results in regards to implant prosthetic components mechanical complications.

Conclusion This systematic review showed higher stress concentration in the implant prosthetic components regarding using platform switched implants, more randomized controlled clinical trials with bigger samples are needed to confirm our findings, but the current evidence demonstrates that non-significant differences between platform switching concept and platform matching. It is recommended to further investigate the mechanical complications that might arise when platform switching concept is used.

INTRODUCTION

An important criterion for the success of dental implants is the presence of good amount and quality of bone around the implants. Bone preservation should always be considered while planning for implant placement (1). Bone loss could be related to implant-abutment relationship, where implant and abutment components have matching diameter, where the inflammatory cell infiltrate will be concentrated at the outer edge of the implant abutment junction in direct approximation to the crestal bone. This may explain the biologic and radiographic observation of bone loss around restored osseointegrated implants (2).
The original criteria established for assessing implant success and survival, identified marginal bone levels as an important indicator for measuring the response of the peri-implant tissues to functional loading (3). It has been observed that some degree of bone resorption occurs at the crest of bone following implant placement (4). Marginal bone loss (MBL) seems to be unavoidable after implant placement, especially after the abutments are connected.
With the improvement in implant industry, the current theory of the benefit of platform switching evolved which is related to the physical repositioning of the implant-abutment junction away from the outer edge of the implant and the surrounding bone, thereby containing the inflammatory infiltrate within the width of the platform.
Lazzara and Porter (5) theorized that less bone loss occurred when using platform switching technique because shifting the IAJ inward also repositioned the inflammatory cell infiltrate and confined it within a 90° area that was not directly adjacent to the crestal bone. From this point, the concept of platform switching in rehabilitation with osseointegrated implants has been increasingly used (6), both in the literature and in implant clinics, because of its promisingly satisfactory results.

Platform switching can be achieved by using abutments with a diameter smaller than the implant neck or body width (7), using an implant design where the neck diameter is increased with respect to the implant body width freeing the extension of the implant platform between 0.5-0.75 mm (7). Using implants with a reverse conical neck, referred to as Bone Platform Switching (8), involves an inward bone ring in the coronal part of the implant that is in continuity with the alveolar bone crest. However, proximity of implant abutment junction to the alveolar crest in this design does not permit significant reduction in the crestal bone loss (8).
An abutment-implant collar diameter mismatch should be more than or equal to 0.4 mm, so as to have a significant influence on crestal bone loss, as concluded by Adie et al. (9) in their meta-analysis of their studies on platform switching. Avni Jain et al., 2017 (10), found that the effect of platform switching on bone loss is very well documented. Platform switched implants reduce marginal bone loss between 0.05 and 1.4 mm. Many researches and studies have proved that platform switching system removed the concentration of stresses from the peri-implant bone margin and reduced its effect on marginal bone resorption, but reviewing the dental literature revealed that there are still some controversies about the biomechanical effect of platform switching technique on implant prosthetic components regarding strain development.
Biomechanical implant prosthetic complications could commonly include fracture or loosening of implant/prosthesis components as abutments or screws and even implant fracture. These complications should be avoided to ensure the long-term stability of implant-supported prostheses (11).

Aim of the research

The objectives of the current systematic review study was to evaluate the available evidence in literature, on the effect of platform switching implants on implant prosthetic components mechanical complications.

METHODS

Search strategy

This systematic literature review was conducted considering the PICO format. The PICOs (population, intervention, comparison, and outcome) question was stated as follows: Will the platform switching technique affect the implant prosthetic components regarding mechanical complications and failures? The purpose was to find any differences, between platform switching implants (PS) compared to platform matching ones (PM), in terms of implant prosthetic parts complications and implant survival.

Electronic databases search

The inclusion criteria (Table 1) and the exclusion criteria (Table 2) were selected. In order to identify the research question, two electronic databases were used as sources in the search for studies satisfying the inclusion criteria: (a) the National Library of Medicine (MEDLINE via PubMed) and (b) Cochrane Central Register of Controlled Trials. These databases were searched for studies published in the last ten years until July 2018.

Selection criteria

The following search terms were used. Population [MeSH terms]: Dental implants OR root form implants OR Endosseous Dental Implants, OR Dental Implantation.
Comparator [MeSH terms]: Regular platform implant OR implant-abutment matching diameter OR non-platform switch implants OR Non-platform switched implants.
Intervention [MeSH terms]: Platform switching OR implant-abutment mismatch diameter OR switching implant platform OR implant platform switched.
Outcome [MeSH terms]: Implant mechanical complications OR implant prosthetic complications OR implant mechanical problems OR implant technical complications.
Then combinations [Population AND Intervention AND Comparator].
URL: ((((((dental implants) OR root form implants) OR Endosseous Dental Implants) OR Dental Implantation))

1	*In vitro* studies
2	Randomized controlled trials (RCTs), controlled clinical trials (CCTs) with at least 12 months follow-up after abutment connection
3	Sample size with a minimum of 10 (5 per group in controlled studies)
4	Systemically healthy patients requiring at least one abutment connected to an implant
5	Fixed prosthetics (single crowns, FPDs)
6	In English language

TABLE 1 Inclusion criteria.

1	Case Reports
2	Animal studies
3	In-vivo studies with a retrospective design
4	Studies investigating mini-implants and/or orthodontic anchorage devices
5	Studies evaluating the behavior of abutments used to retain removable prosthesis
6	Uncontrolled randomized clinical trials
7	Review (systematic or ordinary)
8	Unpublished articles

TABLE 2 Exclusion criteria.

AND ((((Regular platform implant) OR implant-abutment matching diameter) OR non platform switched implants) OR non-platform switch implants)) AND ((((Platform switching) OR implant-abutment mismatch diameter) OR switching implant platform) OR implant platform switched).

Data collection and analysis

The studies collected after the described protocol (Fig. 1) were assessed by 2 authors (AA and KF). The studies full texts were read by authors (AA, CH and KF) and independently assessed according to the inclusion criteria. For deeper knowledge hand search was done in the studies included during primary research. The contents of some reputed journals were independently searched by 2 authors (AA and KF) for related studies available up to July 2018. This was performed to detect any studies which may be lost in the earlier step. The included studies were checked among all the authors for any divergence.

Study selection

The 61 articles were screened independently by two reviewers (AA and KF) through titles and abstracts. In case articles met the inclusion criteria and had no sufficient data to take optimum choice, the full text was gotten. The full reports that were collected from the different electronic and hand searches were checked independently by two authors (AA and CH) to get an absolute decision on whether these articles met the inclusion criteria or not. Disagreements were resolved among authors by open discussion. 11 studies met the inclusion criteria (Table 3), data extraction was done under constant protocol.

No	Title	Author	year	Journal	Source
1	Three-dimensional finite element analysis of platform switched implants (21)	Moon	2017	J Adv Prosthodont	PubMed
2	Effect of different types of prosthetic platforms on stress-distribution in dental implant-supported prosthesis (22)	Minatel	2017	Mater Sci Eng C Mater Biol Appl	PubMed
3	Survival and failure modes: platform-switching for internal and external hexagon cemented fixed dental prostheses (23)	Anchieta	2016	Eur J Oral Sci	PubMed
4	Platform-Switching for cemented versus screwed fixed dental prostheses: reliability and failure modes (24)	Anchieta	2016	Clin Implant Dent Relat Res	PubMed
5	The effect of platform switching on stress distribution in implants and periimplant bone studied by nonlinear finite element analysis (25)	Liu	2014	J Prosthet Dent	PubMed
6	Short implants with a nanometer-sized CaP surface provided with either a platform-switched or platform-matched abutment connection in the posterior region: a randomized clinical trial (26)	Telleman	2013	Clin Oral Implants Res	PubMed
7	Biomechanical evaluation of internal and external hexagon platform switched implant-abutment connections: An *in vitro* laboratory and three-dimensional finite element analysis (27)	Freitas-Júnior	2012	Dent Mater	PubMed
8	Impact of platform switching on peri-implant bone remodeling around short implants in the posterior region, 1-year results from a split-mouth clinical trial (28)	Telleman	2014	Clin Implant Dent Relat Res	PubMed
9	Impact of platform switching on inter-proximal bone levels around short implants in the posterior region; 1-year results from a randomized clinical trial (29)	Telleman	2012	J Clin Periodontol	PubMed
10	Analyzing the effects of the platform-switching procedure on stresses in the bone and implant-abutment complex by 3-dimensional FEM analysis (30)	Cimen	2012	J Oral Implantol	PubMed
11	Stress distribution in the abutment and retention screw of a single implant supporting a prosthesis with platform switching (31)	Alvarez-Arenal	2013	Int J Oral Maxillofac Implant	Manual search

TABLE 3 List of included articles:

No.	Title of the article	Source	Reason for exclusion
1	Platform switching versus regular platform implants: 3-year post-loading results from a randomised controlled trial (12)	PubMed Cochrane	No data about prosthetic complications
2	A Platform switching vs regular platform implants: nine-month post-loading results from a randomised controlled trial (13)	PubMed Cochrane	No data about prosthetic complications
3	The biomechanical effect of platform switching on external- and internal-connection implants (14)	PubMed	No data about prosthetic complications
4	Inward-inclined implant platform for the amplified platform-switching concept: 18-month follow-up report of a prospective randomized matched-pair controlled trial (15)	PubMed	No data about prosthetic complications
5	Regular and platform switching: bone stress analysis varying implant type (16)	PubMed	Stress concentration around bone
6	Load fatigue performance of conical implant-abutment connections (17)	PubMed	Different implant designs
7	Photoelastic analysis of the influence of platform switching on stress distribution in implants (18)	PubMed	Stress concentration around bone
8	Platform-switched restorations on wide-diameter implants: a 5-year clinical prospective study (19)	PubMed	No data about prosthetic complications
9	Biomechanical analysis on platform switching: is there any biomechanical rationale? (20)	PubMed	No outcome data

TABLE 4 List of excluded studies with reasons.

Studies rejected at this stage or following stages were collected. A table for the excluded studies and the reasons for exclusion is reported (Table 4).

Data extraction

Independently using constant designed data extraction forms, fourteen studies underwent data extraction by two review authors (AA, KF). Any disagreements among authors were debated in open discussion and two review authors (HK and CH) were consulted.

For each included study, the following extracted data were listed: year of publication, number of patients (samples per group), and number of implants inserted, place of positioning, implant diameter and length, length of mismatch, type of implants and reported outcomes.

Measure of effect size

Treatment success i.e. survival rates, was measured on a binomial scale or a binary outcome. Odds ratio was calculated as a measure of effect size when comparing between PS (Intervention group) and PM (control group).

Assessment of heterogeneity

Heterogeneity was assessed by checking the graphical display of the estimated treatment effects from each study in the forest plots and their 95% confidence intervals. Also tests of homogeneity analysis were performed to estimate the I^2 statistic. The I^2 statistic is classified according to the Cochrane Handbook for Systematic Reviews of Interventions (32), where 0% to 40% might not be important, 30% to 60% may represent moderate heterogeneity, and 50% to 90% may represent substantial heterogeneity and 75% to 100% considerable heterogeneity. The validity and assessment of the observed value of I2 depends on the significance of the p-value of the test of homogeneity.

Data synthesis (qualitative and quantitative)

The meta-analysis was conducted using Mantel-Haenszel method. Both random and fixed effects models were performed to calculate pooled estimate of effect. Statistical package used for this study: R version 3.4.0 (21-04-2017). Copyright (C) 2017 the R Foundation for Statistical Computing (33).

RESULTS

The electronic search found 80 studies (Fig. 1) and the manual search provided 1 additional publication. After abstract examination, 61 articles of 81 were excluded because not comparing one or more PM groups with one or more PS groups, but investigating the impact of implant micro- or macro-design, abutment materials, sinus lift or ridge augmentation, implant systems, implant surgery techniques or prosthesis' materials. 20 articles of 81 were included in this review because they were analyzing the role of platform switching after a comparison between PS and PM groups, and were in agreement with the inclusion criteria.

Nine articles were excluded out of twenty articles. Six articles showed no data about prosthetic complications

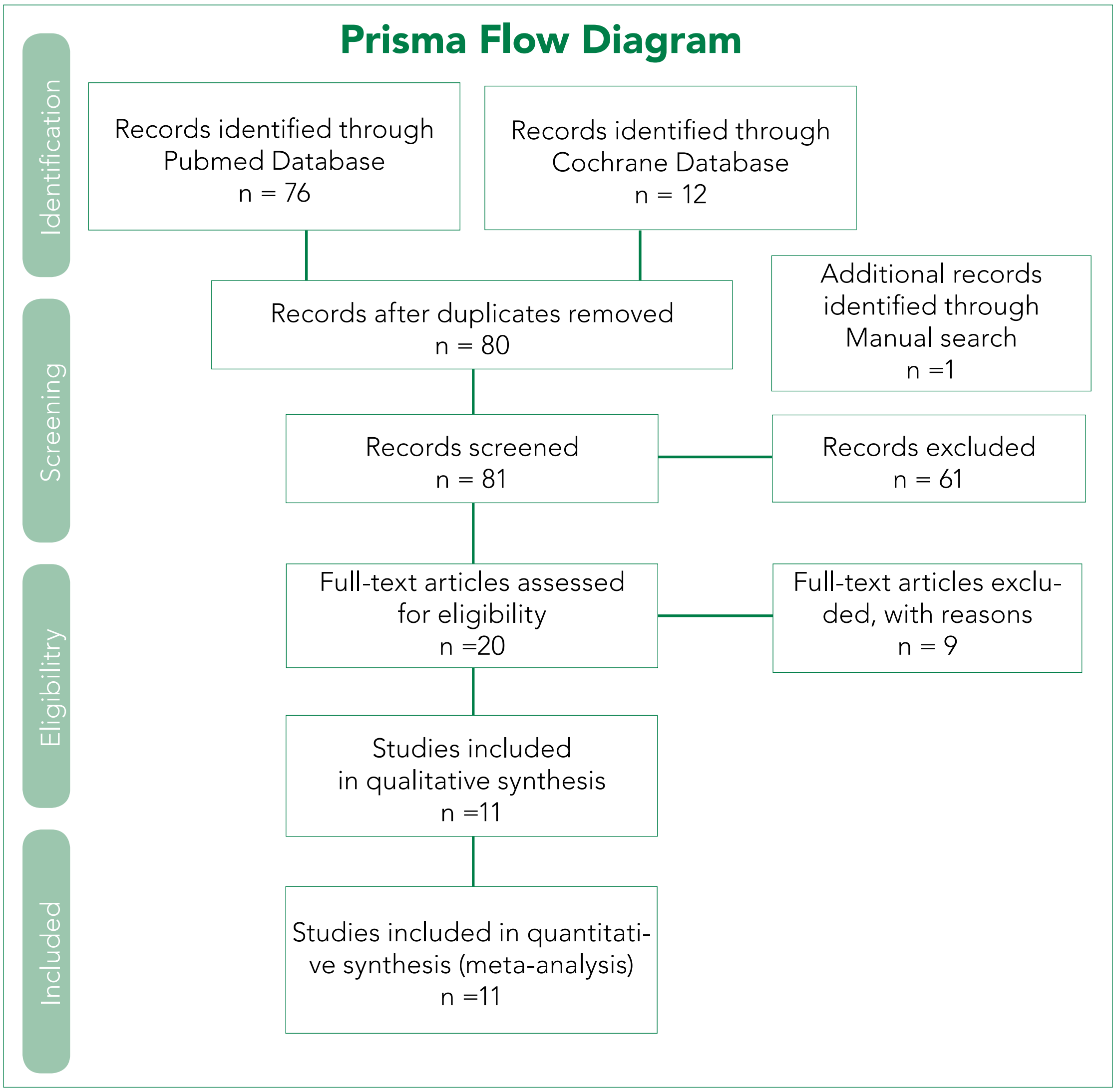

FIG.1 Search study and screening for eligibility and final number of included publications.

(12-15, 19, 20), one was excluded because it used other implant designs (17), and 2 articles were evaluating the effect of platform switching on bone level and not prosthetic components (16, 18).
Thus, this review was finalized with 11 articles. The main characteristics of included publications are in Table 5. The selected studies were published between 2012 (27, 29, 30) and 2017 (21, 22). The number of implant was from 1 (21, 25, 30, 31) up to 84 (23, 24).
Five studies reported results obtained from mandibular sites (21, 23, 24, 25, 31), two studies reported data from maxilla (22, 27) and in three articles implants were placed in mandibular as well in maxilla (26, 28, 29).
All implant samples included titanium, root form, tapered implants. The implant length varied from 8.5mm (26, 28, 29) to 13 mm (25, 31); the diameters were from 4 mm (23-26, 28-30) to 5.5 mm (27); the mismatch used ranged from 0.125 mm per side (21, 22, 27) to 0.5 mm per side (25) (Table 6). The comparison of reported outcomes from primary prosthetic complications to secondary outcomes are reported in Table 7.

The implant failure reported ranged from 0% (24) survival rate up to 99% in platform switching connection (27) versus from 23% (24) to 99 % (27) survival rate in regular platform connection.

Effect of implant abutment connection

The treatment effect of each study group was compared. The pooled estimate represents the Odds Ratio. It is equal to odds of survival of the intervention group; i.e. platform switching connection divided by that of the control group; i.e. platform matching connection.
The data from 389 implant-abutment connections were included in the pooled meta-analysis taking into account the research studies with survival rates outcomes for a more homogenous statistical analysis between 195 Platform switching connections and with 194 platform matching connections (Fig. 2).

Meta-analysis results

As shown in Figure 2 and Table 8, the meta-analysis of the studies showed that the odds of survival in the platform matching connection arm are 2.13 times higher compared to the platform switching arm (P-value= 0.0316). For the random effects model, the odds of survival in the PS arm is not statistically significantly different compared to the PM arm (p-value= 0.2224). The I^2 statistic is 57% (p-value =0.04), which indicates substantial heterogeneity of the included studies results. Therefore, it is recommended to further investigate the difference in treatment effects between both groups.

DISCUSSION

This systematic review was conducted to investigate the impact of platform switching on mechanical complications of implant-supported restoration. The theory of platform switching is more and more pursued because it can be advantageous in several clinical conditions. Previous studies (38, 39) have confirmed that platform-switched abutments may not only reduce the early peri-implant bone loss and increase the biomechanical care presented

Study	Study design	Sample		Implant Location	No. of Sample/ Group	No. of groups	Follow -up
		Patient No.	Implant No.				
Moon SY 2017 (21)	In vitro study (FEA)	NA	PS 1 PM 1	Mandibular first molar	NA	2 FEA Models	NA
Minatel L 2017 (22)	In vitro Study (FEA)	NA	PS 2 PM 2	Upper Second molar region (Type III bone)	NA	4 FEA Models	NA
Anchieta RB 2016 (23)	In vitro study	NA	PS 84 PM 84	Pontic is first molar (3 unit bridge)	21	4 groups	NA
Anchieta RB 2016 (24)	In vitro study	NA	PS 84 PM 84	First molar pontic (3 unit bridge)	21	4 groups	NA
Liu S 2014 (25)	In vitro study (FEA)	NA	PS 1 PM 1	Mandibular right molar region	NA	2 FEA Models	NA
Telleman 2013 (26)	RCT	PS 45 PM 47	PS 73 PM 76	Posterior upper and lower arch	PS 73 PM 76	2 groups	1 month & 1 year.
Freitas-Júnior AC 2012 (27)	In vitro study (FEA)	NA	PS 42 PM 42	Maxillary central incisor	21	4 FEA Models	NA
Telleman 2014 (28)	RCT	PS 17 PM 17	PS 31 PM 31	Posterior upper and lower arch	17	2 groups	1 year
Telleman 2012 (29)	RCT	PS 40 PM 38	PS 52 PM 54	Posterior premolar and molar upper and lower arch	PS 41 PM 39	2 groups	1 year
Cimen H 2012 (30)	In vitro study FEA	NA	PS 1 PM 1	NP	NA	2 FEA Models	NA
Alvarez-Arenal A 2013 (31)	In-Vitro study FEA	NA	PS 1 PM 1	Posterior lower molar region	NA	2 FEA Models	NA

PS= Platform switching. - PM= platform matching. - NA = Non-applicable. - N.P= Not provided.

TABLE 5 Comparison of the main characteristics of included publications features in the present review.

Study	Implant length	Implant diameter	Abutment diameter	Mismatch per side	Type of implant or connection	Survival rate %	Highest von Mises stress values MPa
Moon 2017 (21)	10 mm	5mm	PM 5mm PS 4 mm	0.5 mm	USII Osstem, Pusan, Korea (External hex system)	NP	(300 N load) PS 830 Mpa PM 107.41 Mpa
Minatel 2017 (22)	mm	5 mm	PM 5 mm PS 4 mm	0.5 mm	Arujá, São Paulo, Brazil. (External hexagon connection)	NP	(200 N load) PM 0.92 MPa PS 2.22 MPa
Anchieta 2016 (23)	10 mm	External Hex 4.1 mm	External Hex PM 4.1 mm PS 3.5 mm	0.3 mm	Emfils; Colosso Evolution System, It_u, SP, Brazil (External connection and Internal connection)	EPM (95%) EPS (74%)	NA
		Internal Hex 4 mm	Internal Hex PM 4 mm PS 3.3 mm	0.35 mm		IPM (98%). IPS (59%)	NA
Anchieta 2016 (24)	10 mm	4 mm	PM 4 mm PS 3.3 mm	0.35 mm	Emfils; Colosso Evolution System, Itú, SP, Brazil (Internal connection)	Cement retained PM – 98% PS – 59%	NA
						Screw-retained PM – 23% PS – 0%	NA
Liu 2014 (25)	13 mm	4 mm	PM 4 mm PS 3.75 mm	0.125 mm	Dentsply Implants Anthogyr SAS	NP	(100 N load) PM 166.7 MPa PS 769.0 MPa
Telleman 2013 (26)	8.5 mm	5mm	PM 5mm PS 4.3mm	0.175 mm	XP certain (PM) Certain prevail (PS)	PM 92.1 % PS 95.9%	NA
		4mm	PM 4mm PS 3.2mm	0.2 mm			
Freitas-Júnior AC 2012 (27)	11.5 mm	External Hex 5 mm	External Hex PM 5 mm PS 4.1 mm	0.45 mm	SIN implants, São Paulo, SP, Brazil (Internal hex and External hex)	93% EPM 53% EPS	(300 N load) Abutment EPM 129 MPa EPS 182 MPa IPM 108.3 MPa IPS 166 MPa
		Internal Hex 5.5 mm	Internal Hex PM 5.5 mm PS 4.5 mm	0.5 mm		99% IPM 99% IPS	Screw EPM 305 MPa EPS 365 MPa IPM 242 MPa IPS 270 MPa
Telleman 2014 (28)	8.5 mm	5mm	PM 5mm PS 4.3mm	0.175 mm	XP certain (PM) Certain prevail (PS)	PM 93.6% PS 93.6%	NA
		4mm	PM 4mm PS 3.2mm	0.2 mm			
Telleman 2012 (29)	8.5 mm	5mm	PM 5mm PS 4.3mm	0.175 mm	XP certain (PM) Certain prevail (PS)	PM 93.1 % PS 94.5%	NA
		4mm	PM 4mm PS 3.2mm	0.2 mm			
Cimen H 2012 (3')	11mm	4 mm	PM 4 mm PS 3.2 mm	0.4 mm	NP	NP	(100 N load) Abutment PM 146 MPa PS 404 MPa
							Screw PM 51 MPa PS 78 MPa
Alvarez-Arenal A 2013 (31)	13 mm	4.1 mm	PM 4.1 mm PS 3.8 mm	0.15 mm	Osseo speed	NP	(150 N load) Abut-ment PS 39.5 MPa PM 36.08 MPa
							Screw PS 20.5 MPa PM 16.6 MPa

NP = Not Provided - PS = Platform Switching - EPS = External hex Platform switching - EPM = External hex Platform matching - IPS = Internal hex Platform switching - IPM = Internal hex Platform matching - PM = Platform Matching - NA = Non-applicable.

TABLE 6 Comparison of implant survival rates and other main features of the implants included in the research.

Study	Primary prosthetic complications	Secondary outcomes
Moon 2017 (21)	Highest von Mises stresses in platform switching model components compared with bone	Screw loosening and implant system component fracture for platform switching models
Minatel 2017 (22)	Retaining screws showed greater areas of stress concentration for platform switching abutments	Implant's diameter was a very important factor in the biomechanics of the bone tissue, the dental implant, the retaining screw, and the prosthetic components
Anchieta 2016 (23)	Platform switching decreased the probability of survival of FDPs on both external and internal connections	Failures mainly involved the abutment screw (Screw fracture) and few abutment fractures
Anchieta 2016 (24)	Higher survival rate was observed for matching platform compared with platform switching configurations	Screw-retained FDPs failed by abutment-screw fractures, whereas cement-retained presented implant/screw/abutment fractures
Liu 2014 (25)	Highest von Mises stresses was seen in the platform-switched implant connection	A greater risk of implant fracture may be found with platform-switched, and high-strength abutments should be chosen to prevent fracture
Telleman 2013 (26)	Implant survival, clinical parameters, and patient's satisfaction were independent of the implant–abutment connection design	Short implants with a platform-switched implant–abutment connection showed less peri-implant bone loss
Freitas-Júnior 2012 (27)	Platform-switched implants result in increased stress concentration within the implant-abutment connection	Lower reliability for external hex implants, unlike internal hex implants Highest level of stress was observed in the fixation screw for all models
Telleman 2014 (28)	Implant survival, clinical parameters, and patient's satisfaction were independent of the implant–abutment connection design	Peri-implant bone loss is statistically better when using platform switching
Telleman 2012 (29)	With regard to implant survival, clinical parameters and patients' satisfaction both designs showed similar favorable results	Crestal bone resorption may be reduced by platform switching
Cimen 2012 (30)	Platform-switching connection increased the stress in the abutment	Platform-switching shifts the stress concentration area away from the cervical bone
Alvarez-Arenal 2013 (31)	Platform switching reduced the stresses on the abutment and screw than in conventional model	The location and the distribution of stresses is the same for both models

TABLE 7 Comparison of the outcomes of the included publications in the present review.

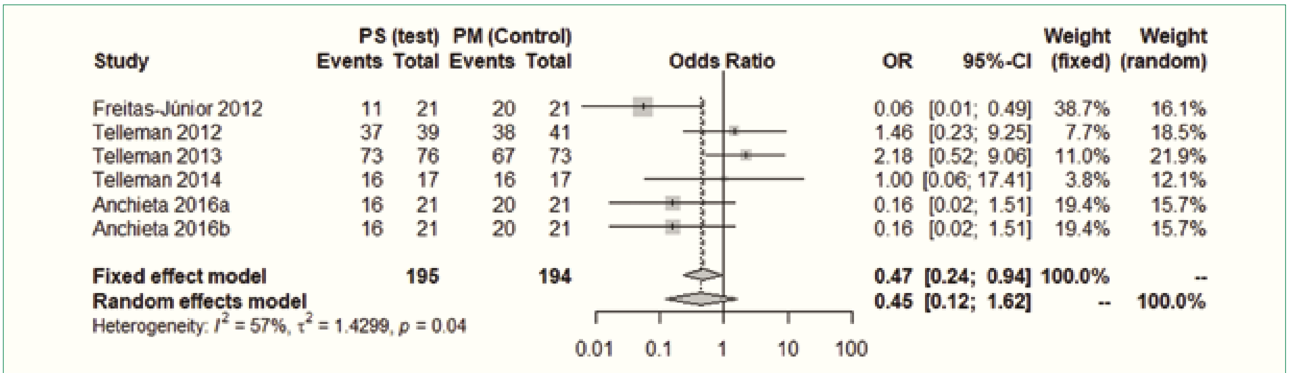

FIG. 2 Comparison between PS and PM - outcome: survival rates.

Study		Odds ratio	95% CI
1	Freitas-Júnior 2012	0.06	[0.01 - 0.49]
2	Telleman 2012	1.46	[0.23 – 9.25]
3	Telleman 2013	2.18	[0.52 – 9.06]
4	Telleman 2014	1	[0.06– 17.41]
5	Anchieta 2016a	0.16	[0.02 – 1.51]
6	Anchieta 2016b	0.16	[0.02 – 1.51]
Fixed effects model		0.47	[0.24– 0.94]
Random effects model		0.45	[0.12 – 1.62]

TABLE 8 Comparison between PM and PS regarding survival rates.

to the implant, but also may enhance esthetics.
Baumgarten et al. (40), advocated that the platform switching method is beneficial w hen s horter i mplants are used, when implants are placed in esthetic area, and when a larger implant is desirable but prosthetic space is limited. However, this systematic review investigated the idea that such attempt to reduce the bone remodeling and resorption and at the same time increase esthetics by reducing abutment diameter may result in higher stress concentration in the prosthetic components.
The heterogeneity among the study conditions is supposed to have some influence on the study outcomes, there were no statistically significant d ifferences b etween i mplant survival rates between platform switching and regular platform implants. Yet, the possible disadvantages of using the implants with the platform switching concept is evident: in this study, which included searches as shown by odds of survival, the platform matching connection arm are 2.13 times more compared to the Platform switching arm (P-value= 0.0316) (21-25, 27).
The postulated hypothesis that there are differences in survival and failure modes between matched and switched platform, was partially accepted. Previous reported studies and systematic reviews investigated the differences in marginal bone loss in different implant abutment connections which might be biological in nature rather than mechanical, which is of the same importance regarding survival rates.
Considering these results, the platform switched implant might have mechanical disadvantages compared to the wide platform implant. In the wide platform implant, more favorable mechanical features including a wide hex connection structure can be expected. Although there have not been any reports of remarkable drawbacks in using the platform switched implant (34), the stress concentration on the prosthetic components can be a serious disadvantage.
The stress concentrations of the prosthodontic components from both the finite e lement a nalysis a nd R CT s tudies, especially platform switching seemed undesirable in terms of mechanical properties and might lead to mechanical complications including screw loosening and component fracture in implant system (21, 23, 24, 35).
Besides the stress concentration on the superstructure components, there might be other disadvantages to the platform switching concept. In platform switching, there is the limitation of having the same screw access hole size and requiring sufficient space for the development of the emergence profile (21).
The failure modes were similar for all groups. Fractures of the abutment screw were more common in groups with internal hexagon implants. External hexagon implants presented complex failure modes, such as fractures of the abutment screw chiefly associated with fracture of the implant, which was less commonly observed in the internal hexagon groups (23, 27). Furthermore, fracture of the abutments detected in groups with internal hex implants were always found on the lingual side at the narrowest area below the cervical collar. The thinnest part of a component is usually its weakest fragment because it is the area where the maximum stresses happen, because of the smallest cross-sectional area. The peak of von Mises stresses was positioned at the external area of the cervical collar because of the connection between abutment and implant (27).
Failure site is related to the design features of the implant-abutment combination, which is usually located in the threaded areas that characterize a critical fact for prosthetic component's durability due to the alteration in geometry along its length and change in cross-sectional area (27, 41).
Although there was no significant difference in survival and in characteristic strength between the platform-switched groups and regular platform, the lower probability of survival observed for the external hexagon connection may result in a reduced mechanical performance (27, 37).
It should be distinguished, that due to engineering plan limitations such as minimum wall thickness for right mechanical performance of each of the different connection systems, alterations in both external and internal geographies of the implant, abutment, and screw designs will occur.
Regarding the geometry of implant connection (internal vs. external), higher reliability and survival was observed in samples with internal connection irrespective of the abutment diameter. These conclusions are in agreement with other studies that found that profound joints show better stability which is more favored than structural strength of implant systems (42, 43).
The systematic review data showed that, the highest probability of survival was observed for the cemented matching implant-abutment platform, followed by the platforms switched cemented and regular-platform screwed (not significantly different from each other), with the least survival for screwed platform switched (24).
Despite an advantageous outcome with regard to the bone, demanding control and maintenance of the implant-

supported prostheses are required; this is because using the platform switch theory shifts the stress to the area of the retaining screw and abutment, which can increase the chance of fracture or failure in the prosthetic components (20, 36).
One of the reasons that the results of this systematic review showed non-significant outcomes is the small mismatch per side between the platform-switched abutments and regular diameter abutments applied in our included research studies (23, 24, 25, 26, 28, 29, 31). Bigger mismatch is often caused, as in the current study, by the use of a narrow diameter (9). Atieh et al., stated that these implants may preserve inter-implant bone height, but they could not confirm the validity of that concept (9).

CONCLUSION

Within the limits of the present work and due to the heterogeneity of the included studies, it could be concluded that although, survival rates outcome were non-significant in the platform switching model compared to those of wide platform model, the stress concentration generated from platform switching concept in the implant and the prosthetic components, mechanical complications might occur. More randomized controlled clinical trials with bigger samples are needed to confirm our findings.

Clinical implications

This systematic review aimed to evaluate mechanical prosthetic complications when platform switching implants are used although proving significant crestal bone preservation advantage.

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

1. Al Sawai A, Rajmohan C, Labib H, Tabiuk S. Advances in dental implant positioning techniques and their clinical implications. Open J Stomatology 2017; 7: 121-35.
2. Al Amri M, Al-Johany S, Al Baker A, Al Rifaiy M, Abduljabbar T and Al-Kheraif A. Soft tissue changes and crestal bone loss around platform-switched implants placed at crestal and subcrestal levels: 36 month results from a prospective split-mouth clinical trial. Clin Oral Implants Res 2016; 31: 430-41.
3. Tarnow D, Cho S, Wallace S. The effect of inter-implant distance on the height of inter-implant bone crest. J Periodontol 2000; 71:546–49.
4. Vijayalakshmi R, Ramakrishnan T. Platform switch dental implants – Search for evidence: An overview. SRM J Res Dent Sci 2016; 7:101-5.
5. Lazzara R, Porter S. Platform switching: a new concept in implant dentistry for controlling post restorative crestal bone levels. Int J Periodontics Restorative Dent 2006; 26:9–17.
6. Ekstein J, Tandelich M, Nart J, Calvo Guirado JI, Shapira I Marginal bone level around conical connection tapered implants with platform switching: A multicenter retrospective study at 14 months follow-up. J Osseointegr 2016;8(1):3-7.
7. Canay S, Akça K. Biomechanical aspects of bone-level diameter shifting at implant-abutment interface. Implant Dent 2009; 18: 239-48.
8. Carinci F, Brunelli G, Danza M. Platform switching and bone platform switching. J Oral Implantol 2009; 35: 245-50.
9. Atieh M, Ibrahim H and Atieh A. Platform switching for marginal bone preservation around dental implants: A systematic review and meta-analysis. J Periodontol 2010; 81: 1350-66.
10. Avni J, Vinaya B, and Chethan H. Oral peri-implant bone loss: platform switching or shifting?-a review. Int J Recent Sci Res 2017; 8: 17239-241.
11. Zembic A, Kim S, Zwahlen M, Kelly R. Systematic review of the survival rate and incidence of biologic, technical, and esthetic complications of single implant abutments supporting fixed prostheses. Int J Oral Maxillofac Implants 2014; 29: 99–116.
12. Meloni SM, Jovanovic SA, Pisano M, Tallarico M. Platform switching versus regular platform implants: 3-year post-loading results from a randomised controlled trial. Eur J Oral Implantol 2016; 9: 381-390.
13. Meloni SM, Jovanovic SA, Lolli FM, Pisano M, De Riu G, De Riu N, Lugliè PF, Tullio A. Platform switching vs regular platform implants: nine-month post-loading results from a randomised controlled trial. Eur J Oral Implantol 2014; 7: 257-65.
14. Yang TC, Maeda Y. The biomechanical effect of platform switching on external- and internal-connection implants. Int J Oral Maxillofac Implants 2013; 28:143-7.
15. Canullo L, Rosa JC, Pinto VS, Francischone CE, Götz W. Inward-inclined implant platform for the amplified platform-switching concept: 18-month follow-up report of a prospective randomized matched-pair controlled trial. Int J Oral Maxillofac Implants 2012; 27:927-34.
16. Gurgel-Juarez NC, de Almeida EO, Rocha EP, Freitas AC Jr, Anchieta RB, de Vargas LC, Kina S, França FM. Regular and platform switching: bone stress analysis varying implant type. J Prosthodont 2012; 21:160-6.
17. Seetoh YL, Tan KB, Chua EK, Quek HC, Nicholls JI. Load fatigue performance of conical implant-abutment connections. Int J Oral Maxillofac Implants 2011; 26: 797-06.
18. Pellizzer EP, Falcón-Antenucci RM, de Carvalho PS, Santiago JF, de Moraes SL, de Carvalho BM. Photoelastic analysis of the influence of platform switching on stress distribution in implants. J Oral Implantol 2010; 36:419-24.
19. Vigolo P, Givani A. Platform-switched restorations on wide-diameter implants: a 5-year clinical prospective study. Int J Oral Maxillofac Implants 2009; 24:103-9.
20. Maeda Y, Miura J, Taki I, Sogo M. Biomechanical analysis on platform switching: is there any biomechanical rationale? Clin Oral Implants Res 2007;18: 581-4.
21. Moon SY, Lim YJ, Kim MJ, Kwon HB. Three-dimensional finite element analysis of platform switched implant. J Adv Prosthodont 2017; 9: 31-37.
22. Minatel L, Verri FR, Kudo GAH, de Faria Almeida DA, de Souza Batista VE, Lemos CAA, Pellizzer EP, Santiago JF Junior. Effect of different types of prosthetic platforms on stress-distribution in dental implant-supported prostheses. Mater Sci Eng C Mater Biol Appl 2017; 71:35-42.
23. Anchieta RB, Machado LS, Hirata R, Coelho PG, Bonfante EA. Survival and failure modes: platform-switching for internal and external hexagon cemented fixed dental prostheses. Eur J Oral Sci 2016; 124:490-97.
24. Anchieta RB, Machado LS, Hirata R, Bonfante EA, Coelho PG. Platform-switching for cemented versus screwed fixed dental prostheses: reliability and failure modes: an in vitro study. Clin Implant Dent Relat Res 2016; 18: 830-9.
25. Liu S, Tang C, Yu J, Dai W, Bao Y, Hu D. The effect of platform switching on stress distribution in implants and periimplant bone studied by nonlinear finite element analysis. J Prosthet Dent 2014; 112:1111-8.
26. Telleman G, Meijer HJ, Vissink A, Raghoebar GM. Short implants with a nanometer-sized CaP surface provided with either a platform-switched or platform-matched abutment connection in the posterior region: a randomized clinical trial. Clin Oral Implants Res 2013; 24:1316-24.
27. Freitas-Júnior AC, Rocha EP, Bonfante EA, Almeida EO, Anchieta RB, Martini AP, Assunção WG, Silva NR, Coelho PG. Biomechanical evaluation of internal and external hexagon platform switched implant-abutment connections: An in vitro laboratory and three-dimensional finite element analysis. Dent Mater 2012; 28:e218-28.

28. Telleman G, Raghoebar GM, Vissink A, Meijer HJ. Impact of platform switching on peri-implant bone remodeling around short implants in the posterior region, 1-year results from a split-mouth clinical trial. Clin Implant Dent Relat Res 2014; 16:70-80.
29. Telleman G, Raghoebar GM, Vissink A, Meijer HJ. Impact of platform switching on inter-proximal bone levels around short implants in the posterior region; 1-year results from a randomized clinical trial. J Clin Periodontol 2012; 39: 688-97.
30. Cimen H, Yengin E. Analyzing the effects of the platform-switching procedure on stresses in the bone and implant-abutment complex by 3-dimensional fem analysis. J Oral Implantol 2012; 38: 21-6.
31. Alvarez–Arenal A, Segura-Mori L, Gonzalez-Gonzalez I, Gaco A. Stress distribution in the abutment and retention screw of a single implant supporting a prosthesis with platform switching. Int J Oral Maxillofac Implants 2013; 28: e112-21.
32. Higgins JP, Green S. Cochrane handbook for systematic reviews of interventions. (Vol. 4). John Wiley & sons; 2011.
33. R core team. R: A language and environment for statistical computing. R foundation for statistical computing, Vienna, Austria. URL https://www.R-project.org/.
34. Pessoa R, Vaz L, Marcantonio E Jr, Vander Sloten J, Duyck J, Jaecques S. Biomechanical evaluation of platform switching in different implant protocols: computed tomography-based three-dimensional finite element analysis. Int J Oral Maxillofac Implants 2010; 25: 911-9.
35. Tabata L, Assunção W, Adelino Ricardo Barão V, de Sousa E, Gomes E, Delben J. Implant platform switching: biomechanical approach using two-dimensional finite element analysis. J Craniofac Surg 2010; 21:182-7.
36. Chang CL, Chen CS, Hsu ML. Biomechanical effect of platform switching in implant dentistry: a three-dimensional finite element analysis. Int J Oral Maxillofac Implants 2010; 25: 295–304.
37. Freitas A Jr, Bonfante E, Silva N, Marotta L, Coelho P. Effect of implant-abutment connection design on reliability of crowns: regular vs. horizontal mismatched platform. Clin Oral Implants Res 2012; 23: 1123–26.
38. Cappiello M, Luongo R, Di Iorio D, Bugea C, Cocchetto R, Celletti R. Evaluation of peri-implant bone loss around platform-switched implants. Int J Periodontics Restorative Dent 2008; 28: 347–55.
39. Luongo R, Traini T, Guidone PC, Bianco G, Cocchetto R, Celletti R. Hard and soft tissue responses to the platform-switching technique. Inte J Periodontics Restorative Dent 2008; 28: 551–7.
40. Baumgarten H, Cocchetto R, Testori T, Meltzer A, Porter S. A new implant design for crestal bone preservation: initial observations and case report. Practical Procedures Aesthetic Dentistry PPAD 2005; 17: 735–40.
41. Quek HC, Tan KB, Nicholls JI. Load fatigue performance of four implant-abutment interface designs: effect of torque level and implant system. Intl J Oral and Maxillofacial Implants 2008; 23: 253–62.
42. Maeda Y, Satoh T, Sogo M. In vitro differences of stress concentrations for internal and external hex implant-abutment connections: a short communication. J Oral Rehabilitation 2006; 33:75–8.
43. Steinebrunner L, Wolfart S, Ludwig K, Kern M. Implant-abutment interface design affects fatigue and fracture strength of implants. Clinical Oral Implants Research 2008; 19:1276–84.