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SYSTEMATIC REVIEW

Evaluation of marginal bone loss of dental implants with internal or external connections and its association with other variables: A systematic review

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ABSTRACT

Statement of problem. Different factors can influence marginal bone loss around dental implants, including the type of internal and external connection between the implant and the abutment. The evidence needed to evaluate these factors is unclear.

Purpose. The purpose of this systematic review was to evaluate marginal bone loss by radiographic analysis around dental implants with internal or external connections.

Material and methods. A systematic review was conducted following the criteria defined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Initially, a population, intervention, comparison, and outcome(s) (PICO) question was defined: does the connection type (internal or external) influence marginal bone loss in patients undergoing implantation? An electronic search of PubMed/MEDLINE and Scopus databases was performed for studies in English language published between January 2000 and December 2014 by 2 independent reviewers, who analyzed the marginal bone loss of dental implants with an internal and/or external connection.

Results. From an initial screening yield of 595 references and after considering inclusion and exclusion criteria, 17 articles were selected for this review. Among them, 10 studies compared groups of implants with internal and external connections; 1 study evaluated external connections; and 6 studies analyzed internal connections. A total of 2708 implants were placed in 864 patients. Regarding the connection type, 2347 implants had internal connections, and 361 implants had external connections. Most studies showed lower marginal bone loss values for internal connection implants than for external connection implants.

Conclusions. Osseointegrated dental implants with internal connections exhibited lower marginal bone loss than implants with external connections. This finding is mainly the result of the platform switching concept, which is more frequently found in implants with internal connections. (J Prosthet Dent 2016;116:501-506)

Since their introduction in the 1960s and 1970s, osseointegrated dental implants have been used worldwide to rehabilitate patients with partial or complete edentulism.[1] The evaluation of bone stability is essential to ensure optimal long-term results of osseointegrated implants, because excessive bone loss can result in periimplantitis,[2] which can lead to eventual implant loss. Additionally, the loss of marginal bone height can change the surrounding soft tissue architecture, resulting in the loss of interdental papilla and causing esthetic and phonetic changes and food impaction.[3] Decreases in inflammatory reactions, load concentrations, and bacterial leakage at the implant-abutment interface are closely associated with marginal bone loss.[4,5]

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Clinical Implications

The choice of internal or external connection implants may influence marginal bone loss, but no current consensus has been published as to the best treatment option for minimizing marginal bone loss. Platform switching may be more important to the preservation of marginal bone than the connection type itself.

Several factors can influence marginal bone loss around dental implants, including patient characteristics (smoking and hygiene deficiency or parafunctional habits),[6] prosthesis characteristics (retention method and number of elements), and dental implant characteristics (diameter, surface treatment, and connection type).[7,8]

Various dental implants with different internal and external connection types are available. These connections and how they relate to the implant abutment may influence marginal bone loss.[7] The abutment and the implant can be of equal diameters, or an abutment with a narrower diameter (the platform switching concept) can be used.[7] The connection between the abutment and implant is related to the formation of microgaps, bacterial leakage, micromovements of the abutments, and alteration of biologic width formation, all of which may cause higher or lower marginal bone loss.[9]

Studies have compared the marginal bone loss of several types of implants by considering implant macrodesign, surface treatment, and installation depth. However, few studies have evaluated the marginal bone loss around implants by considering the connection type. Additionally, the authors are unaware of any systematic review that has evaluated the influence of implant connections in bone loss. This systematic review aimed to evaluate the marginal bone loss around dental implants by considering the implant connection type.

MATERIAL AND METHODS

A systematic review was conducted following the criteria defined by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria.[10] Initially, a population, intervention, comparison, and outcome(s) (PICO) question was defined: does the connection type (internal or external) influence marginal bone loss in patients submitted to implant installation? An electronic search of the PubMed/MEDLINE and Scopus databases was performed for studies published in English between January 2000 and December 2014 by 2 independent reviewers (R.A.M. and A.J.V.F.). Any disagreement regarding the inclusion of an article was resolved by discussion or, in the case of unresolved conflicts, by a third reviewer (M.C.G.). Articles related to marginal bone loss around dental implants with internal or external connections were selected by using the Medical Subject Headings (MeSH) keywords "dental implant AND internal connection" and "dental implant AND external connection." Initially, titles and abstracts were read, and after inclusion and exclusion criteria were considered, the full texts were selected for reading and final selection.

Criteria for inclusion were that studies were published in English, they evaluated the marginal bone loss around dental implants with internal or external connections, they evaluated the platform switching concept, that they were randomized, prospective, and retrospective studies.

Studies were excluded because they were not written in English, or they duplicated studies; they were animal or in vitro studies, case reports, interviews, or comments and questionnaire studies, or literature or systematic reviews; they evaluated surgical techniques such as maxillary sinus lifting, implant installation in 1 or 2 stages, new surgical kits and bone grafts; they evaluated implant surface treatments; they assessed abutment height, marginal adaptation and angulation; they did not report marginal bone loss or reported insufficient data concerning the implant connection used; and they assessed nonoral implants.

The factors extracted from the selected studies and analyzed were first author and year, implant connection type, profile of the participants (average age, number of men and women, number of smokers [over 10 cigarettes per day]), quantity and characteristics of the implants (implant diameter/length and manufacturer), arch where the implant was placed, prosthesis type, and bone loss. When the connection type was not described in the study, a search of the implant manufacturer's Website reported in the article was was performed. When the connection type or commercial brand of the implant used was not found, the article was excluded.

RESULTS

A publications search using the keyword phrase "dental implant AND internal connection" yielded 183 articles in the PubMed/MEDLINE database and 195 articles in the Scopus database. After removing duplicated articles and considering the inclusion and exclusion criteria, 16 articles (κ=0.94) remained. For the keyword phrase "dental implant AND external connection," 105 articles were obtained from the PubMed/MEDLINE database and 112 articles from the Scopus database. After the exclusion of duplicated articles and application of inclusion and exclusion criteria, 12 articles were included for full text reading (κ=0.92). After the union of both search results, 17 articles were selected for this review (Fig. 1). Reasons for the exclusion of 2 articles are listed in Table 1. The number of randomized clinical trials that

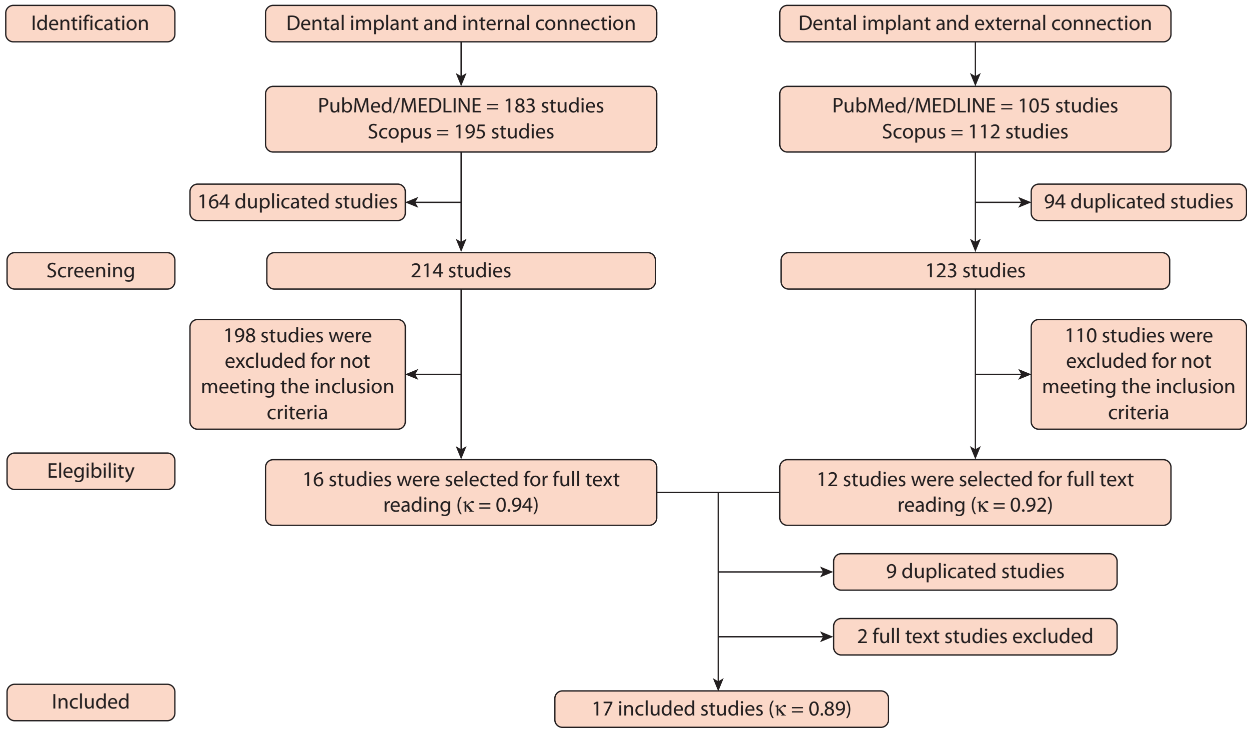

Figure 1. Literature screening process.

compared marginal bone loss with internal and external connections was small. Because data were insufficient to conduct a meta-analysis, they was critically analyzed.

Supplemental Tables 1 to 3 show the results obtained after the selected studies were read. Supplemental Table 1 and Table 2 show the results for studies that compared internal and external connections. Supplemental Table 2 shows studies that evaluated external connections, and Supplemental Table 3 lists data of studies that analyzed internal connections.

Supplemental Table 4 shows the marginal bone loss in different follow-up periods reported in the studies. Oliva et al[11] and Jo et al[12] evaluated only 1 follow-up period, and those data are presented in Supplemental Table 2. Canullo et al[8] did not report marginal bone loss at 6 and 12 months, showing the results only on a graph with approximate values.

The marginal bone loss measured in the studies demonstrates that, over the years, internal connection implants have lower values of bone resorption than external connection implants. Among 10 studies that compared groups with both connection types, 5 studies[4,7,8,13,14] showed that internal connections exhibited lower values of marginal bone loss, with statistically significant difference. Three other articles[15-17] showed no statistical difference between the connections, 1 study[18] presented statistically better performance of external connections, and 1 study[11] did not report statistical analysis, but the results of bone loss were lower for internal connections.

Table 1. Reasons for excluding articles after full text reading

Study	Reason for Exclusion
Jo et al[12] 2013	Insufficient data concerning implant connection used
Drago et al[42] 2006	Insufficient data concerning implant connection used

Additionally, the results demonstrated that implants with platform switching (Supplemental Tables 1-3), regardless of the connection type used, showed reduced bone resorption rates compared with the use of an abutment diameter equal to the implant platform. All internal connection implants used the platform switching concept, except for a group in the study by Pieri et al,[19] where abutments with the same diameter of the implant were placed. For studies using external connection implants, only the study by Vandeweghe and De Bruyn[6] used this approach, installing implants with the platform switching concept on one side and the non-switched concept on the other.

In the 17 studies, a total of 2708 implants were placed in 864 patients (mean age of 43.73 years). The implants were marketed by 10 different companies. Regarding the connection type, 2347 implants had internal connections, and 361 implants had external connections.

Implant diameters ranged from 3.5 mm to 7 mm, and most studies (12 articles) used implants with the conventional platform (3.9-4.5 mm). Among the external connection implants, 14.54% had diameters between 3.5 and 3.8 mm, 65.76% had diameters between 3.9 and 4.5 mm, and 19.7% had diameters larger than 4.5 mm.

Table 2. Studies comparing the mean values of marginal bone loss around implants with internal and external connections

Author	Internal connection (mm)	External connection (mm)
Crespi et al,[15] 2009	0.73	0.78
Kielbassa et al,[17] 2009	0.79	0.64
Peñarrocha-Diago et al,[14] 2013	0.12	0.38
Oliva et al,[11] 2012	0.53	0.84
Arnhart et al,[18] 2012	0.87	0.16
Koo et al,[7] 2012	0.07	0.29
Canullo et al,[8] 2012	0.56	1.63
Lin et al,[16] 2013	0.35	0.32
Pozzi et al,[4] 2014	0.51	1.1
Pozzi et al,[13] 2014	0.67	1.24

Among the internal connection implants, 17.92% had diameters between 3.5 and 3.8 mm, 62.02% had diameters between 3.9 and 4.5 mm, and 20.06% had diameters larger than 4.5 mm.

Implant length ranged from 8 to 16 mm. Shorter implants were not used in the studies. Among the external connection implants, 4.85% had lengths between 8 and 9 mm, 94.55% were between 10 and 13 mm, and 0.60% had implants longer than 15 mm. For the internal connection implants, 0.57% had lengths between 8 and 9 mm, 90.19% were between 10 and 13 mm, and 9.24% had implants longer than 13 mm (14, 15, and 16 mm). Four studies did not report diameter and length of the implants.[2,12,19,20]

Characteristics of the prosthesis used in the included studies are described in Tables 2 to 4. Types of prostheses varied from single crowns to complete-arch prostheses, both implant-supported and implant-retained prostheses (bar overdentures or stud attachment overdentures). Of the screwed and cemented prostheses, the latter were more prevalent.

DISCUSSION

All studies selected for this systematic review evaluated bone loss through radiographic analysis, as the vertical differences between implant platforms and first bone contacts with implant surfaces. This analysis is widely used but has limitations. The evaluation is performed only in the mesial and distal sites of the implant, disregarding any changes in bone profile that occur in the buccal and lingual sites of the implant.[21] Further studies should be performed to evaluate marginal bone loss by using a 3-dimensional imaging method to assess the full bone profile around dental implants.

Most studies showed marginal bone loss values for internal connection implants that were lower than those for external connection implants.[4,7,8,11,13,14] However, only 2 studies[7,8] had a similar macrodesign and surface treatment of the dental implant, differentiating between the groups only by connections. Nevertheless, other factors, related mainly related to participants, may have influenced the results of Koo et al.[7] Additionally, although Canullo et al[8] had placed implants with both types of connections in the same participants, they did not standardize the distance between the implants and did not report whether the procedure was performed by a single surgeon. Additionally, having splinted prostheses may have influenced the results.

Limitations were frequently found in the studies because many factors can influence marginal bone loss. Factors are related to implants (diameter and length, neck design, surface treatment, angulation, immediate or delayed loading, distance between adjacent teeth or implants, installation depth), to prostheses (number of teeth rehabilitated by the prosthesis and their retention, abutment type, antagonist arch), and to the patient (bone type, region needing rehabilitation, parafunctional habits, patient hygiene, smoking habits, systemic factors).[6] However, overcoming those limitations is difficult because of the many different implants on the market and because finding participants with identical profiles who need the same type of prosthesis is difficult. These limitations also influence the differing bone loss values among studies.

Despite these limitations, the majority of studies (n=5) that compared both types of connections showed that internal connection implants reduced marginal bone loss. Those authors[4,7,8,13,14] concluded that the platform switching concept (abutment diameter smaller than implant diameter), which is generally used for implants with this connection type, was largely responsible.[7] This concept is suitable because the implant-abutment interface is distanced from the bone crest, resulting in the dissipation of load concentration, abutment micromovements, and, especially, bacterial colonization in a more distant region of the bone.[14]

Load concentration is located mainly in the implant-abutment interface, reducing the stress concentration of internal connection implants that use the platform switching concept in the periimplant bone region.[22,23] Additionally, the use of this restoration method decreases abutment micromovements[13] during functional loading, preserving the relationship between the periimplant tissue and the implant and reducing bacterial leakage.[24] Platform switching also contributes to the reestablishment of the biological width.[7] The biological width acts against bacterial leakage and is closely related to bone remodeling.[13,16] Corroborating the importance of the platform switching concept, Pieri et al[19] compared 2 internal connection implants, varying the abutment diameter with one smaller than the implant platform and the other with the same diameter. Lower statistically significant values were verified for groups with platform switching.

Although the platform switching concept is used more for internal connection implants, resulting in lower marginal bone values, it can also be used for external connections.[6] Vandeweghe and Bruyn[6] compared external connection implants with platform switching on one side (test group) and with the conventional platform on the other side (control group), obtaining smaller bone loss values in the side with platform switching. In this study, several factors that can influence the outcome were removed, since both groups had the same soft and hard tissues properties, surgical protocol, and patient health and hygiene conditions.[6] The combination of platform switching and external connection implants demonstrated good results,[6] which suggests that, regardless of the connection type (internal or external), this concept can be used. Platform switching may be more important to the preservation of marginal bone than the connection type itself.

In vitro studies indicate that the platform switching concept reduces the stress on the implant neck area in both connection types.[25-28] However, the loads are more concentrated in the implant-abutment interface, which may cause abutment screw deformation or loosening.[23]

Only 1 study found lower marginal bone loss values with external connection implants when compared with those with internal connections.[18] These authors hypothesized that the implant used had an abutment with a tight frictional retention, complicating its handling. Thus, many centers decided to remain with the initial abutment during the treatment, keeping the transgingival interface intact throughout the course of the study. Another factor that may have influenced the results was the geometry of the implant, which has a narrower neck design than the implant body and may favor beneficial bone remodeling.

Other factors influencing marginal bone loss, regardless of the connection type used, are the types of prosthesis retention, smoking habits, distance between implants, and implant diameter and length.[29]

Little consensus on the optimal prosthesis retention system has been reached.[30] Some studies did not demonstrate differences between cemented and screwed prostheses,[31-33] but other studies showed lower bone loss values for screwed prostheses[34] or cemented prostheses.[35] However, excess cement must be avoided,[36] especially when it is located subgingivally,[30] which may result in periimplant alterations and bone loss.[37] Most articles analyzed in the present systematic review used cemented, implant-supported prostheses.

A few studies evaluated marginal bone loss in smokers (over 10 cigarettes per day).[11,19] However, those authors did not show differences between smokers and nonsmokers. The other studies included smokers or patients who consumed more than 10 cigarettes per day in the exclusion criteria. Smoking habits can negatively influence marginal bone loss, especially when related to the patient's hygiene habits.[38] Although Takamiya et al[39] found that smoking cannot be an absolute contraindication to dental implant treatment, smokers should be advised of the greater risks of implant failure.

In the present review, a few studies assessed oral hygiene habits[14] or performed periodontal treatment before implant installation.[20,40] Meyle et al[40] evaluated bone loss with internal connection implants in patients with a history of chronic periodontitis, concluding that the results are satisfactory if infection is properly controlled and periodontal attachment levels are maintained.

Only 1 study analyzed implant diameter and length as factors in bone loss.[14] The authors observed that a reduction in bone loss occurred with the increase in implant diameter and length. Only 1 study evaluated the distance between implants[12] with no differences in marginal bone loss between internal connection implants placed with a interimplant distance smaller or larger than 3 mm. Regarding implant depth, most studies installed implants at the crestal bone level.[4-8,13,14,16,40] Published reports of clinical studies that assessed this condition are scarce. When the implant was not loaded functionally, no differences were found in bone loss between implants placed subcrestally or crestally.[41] When the implant was in function, bone might form on the platform of implants placed subcrestally, resulting in better clinical outcomes after 1 year of loading than for implants placed crestally.[21]

Marginal bone loss is not dependent on only 1 factor, such as the connection type, but on several factors combined that promote bone maintenance or loss. However, considering the limitations of clinical trials and of this systematic review, internal connections performed better than external connections, mainly because of the platform switching concept used. Since some studies showed no statistically significant difference between the connection types and since others concluded that the internal connections have greater stability in bone remodeling, internal connections should be indicated for clinical use when only the marginal bone loss factor is considered.

CONCLUSIONS

Osseointegrated dental implants with internal connections demonstrated lower marginal bone loss values when compared with implants with external connections. This is mainly because of the platform switching concept, which is more frequently used in implants with internal connections.

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Supplemental Table 1. Data collected from studies evaluating marginal bone loss around implants with internal and external connections

Study	Type of Connection	Average (±SD) age	Males/ Females	Number of Smokers (>10 Cigarettes/D)	Number of Implants	Diameter/ Length (mm)	Arch	Mfr	Prosthesis type	Prothesis retention	Mean Bone Loss (±SD) (mm)/ Follow-up Period (mo)
Crespi et al[15] 2009	External: hexagon	48.7	18/27	0	34	3.8 and 5/13	Maxilla and mandible	Sweden & Martina	Provisional acrylic resin prosthesis	Cemented	0.78 (±0.45)/24
	Internal: Morse taper			0	30	4.5 and 5.5/14	Maxilla and mandible	Ankylos-Dentsply	Provisional acrylic resin prosthesis	Cemented	0.73 (±0.52)/24
Kielbassa et al[17] 2009	Internal: Morse taper with antirotational mechanism	49.5 ±13.1	27/37	NR	117	3.5 and 4.3/10, 11.5, 13 and 15	Maxilla and mandible	Nobel Biocare	Single crowns, fixed partial prosthesis or full-arch prosthesis	Screwed or cemented	0.95 (±1.37)/12
	External: Transmucosal implant with antirotational mechanism	49.9 ±13.6	32/21	NR	82	3.5 and 4.3/10, 11.5, 13 and 15	Maxilla and mandible	Nobel Biocare	Single crowns, fixed partial prosthesis or full-arch prosthesis	Screwed or cemented	0.64 (±0.97)/12
	Internal: Morse taper	46.9 ±14.6	26/34	NR	126	3.5 and 4.3/8, 10, 13 and 16	Maxilla and mandible	Nobel Biocare	Single crowns, fixed partial prosthesis or full-arch prosthesis	Screwed or cemented	0.63 (±1.17)/12
Peñarrocha-Diago et al.[14] 2013	Internal: Morse taper	56.9 ±7.8	11/4	0	72	3.75 and 4.25/ 10, 11.5 and 13	Maxilla and mandible	Mozo-Grau	Fixed full-arch prosthesis, bar overdentures or Locator overdentures	NR	0.12 (±0.17)/12
	External: hexagon				69	3.75 and 4.25/ 10, 11.5 and 13	Maxilla and mandible	Mozo-Grau	Fixed full-arch prosthesis, bar overdentures or Locator overdentures	NR	0.38 (±0.51)/12
Oliva et al[11] 2012	Internal: Morse taper	52.88	11/6	8	69	4.1-4.8/10-14	Maxilla and mandible	Straumann and Osstem Implant	Fixed full-arch prosthesis	NR	0.53 (±0.32)/60
	External: hexagon				3	4.1-4.8/10-14	Maxilla and mandible	Osstem Implant	Fixed full-arch prosthesis	NR	0.84 (±0.62)/60
Arnhart et al[18] 2012	Internal: Morse taper with antirotational mechanism	49.5 ±13.1	27/37	NR	117	3.5 and 4.3/10, 11.5, 13 and 15	Maxilla and mandible	Nobel Biocare	Single crowns, fixed partial prosthesis or full-arch prosthesis	Screwed or cemented	0.89 (±1.65)/36
	External: Transmucosal implant with antirotational mechanism	49.9 ±13.6	32/21	NR	82	3.5 and 4.3/10, 11.5, 13 and 15	Maxilla and mandible	Nobel Biocare	Single crowns, fixed partial prosthesis or full-arch prosthesis	Screwed or cemented	0.16 (±1.06)/36
	Internal: Morse taper	46.9 ±14.6	26/34	NR	126	3.5 and 4.3/8, 10, 13 and 16	Maxilla and mandible	Nobel Biocare	Single crowns, fixed partial prosthesis or full-arch prosthesis	Screwed or cemented	0.85 (±1.32)/36
Koo et al[7] 2012	External: hexagon	54.3	15/25	NR	20	4.3/8.5, 10, 11.5 and 13	Maxilla and mandible	NR	Single crowns	NR	0.29 (±0.35)/12
	Internal: octagon			NR	20	4.3/8.5, 10, 11.5 and 13	Maxilla and mandible	NR	Single crowns	NR	0.07 (±0.21)/12
Canullo et al[2,8] 2012	External: hexagon	58.2	24/16	0	40	4/13	Maxilla	PI Branemark	Single 2-unit prosthesis	Cemented	1.63 18
	Internal: Inward-inclined platform			0	40	4/13	Maxilla	PI Branemark	Single 2-unit prosthesis	Cemented	0.49 18
Lin et al[16] 2013	External: hexagon	47 ±11	15/8	NR	33	4-5/10-12	Maxilla and mandible	Nobel Biocare	Single crown and fixed 2-unit prosthesis	Cemented	0.32 (±0.19)/6

(*continued on next page*)

Supplemental Table 1. (*Continued*) Data collected from studies evaluating marginal bone loss around implants with internal and external connections

Study	Type of Connection	Average (±SD) age	Males/ Females	Number of Smokers (>10 Cigarettes/D)	Number of Implants	Diameter/ Length (mm)	Arch	Mfr	Prosthesis type	Prothesis retention	Mean Bone Loss (±SD) (mm)/ Follow-up Period (mo)
	Internal: Morse taper		10/8	NR	37	4-5/10-12	Maxilla and mandible	Friadent	Single crown and fixed 2-unit prosthesis	Cemented	0.32 (±0.14)/6
	Internal: octagon		10/12	NR	33	4-5/10-12	Maxilla and mandible	Cowellmedi	Single crown and fixed 2-unit prosthesis	Cemented	0.38 (±0.22)/6
Pozzi et al[4,13] 2014	Internal Morse taper	52.20 ±5.34	15/19	0	34	3.9/10 and 13	Mandible	Nobel Biocare	Single crowns CAD-CAM	Cemented	0.51 (±0.34)/12
	External: hexagon			0	34	4.1/10 and 13	Mandible	Nobel Biocare	Single crowns CAD-CAM	Cemented	1.10 (±0.52)/12
Pozzi et al[4,13] 2014a	Internal Morse taper	52.20 ±5.34	15/19	0	34	3.9/8.5, 10, 11.5 and 13	Mandible	Nobel Biocare	Single crowns CAD-CAM	Cemented	0.67 (±0.39)/36
	External: hexagon			0	34	4.1/8.5, 10, 11.5 and 13	Mandible	Nobel Biocare	Single crowns CAD-CAM	Cemented	1.24 (±0.47)/36

NR, not reported.

Supplemental Table 2. Data collected from study evaluating marginal bone loss around implants with external connections

Study	Type of Connection	Average (±SD) age	Males/ Females	Number of Smokers (>10 Cigarettes/D)	Number of Implants	Diameter/ length (mm)	Arch	Mfr	Prosthesis Type	Prosthesis Retention	Mean Bone Loss (±SD) (mm)/Follow-up Period (mo)
Vandeweghe and De Bruyn[6] 2012	External: hexagon with platform switching	57 ±13	9/6	0	15	7/9	Maxilla and mandible	NR	Single CAD-CAM crowns	NR	0.66 (±0.47)/12
	External: hexagon without platform switching									NR	0.94 (±0.42)/12

CAD-CAM, computer-aided design and computer-aided manufacture; NR, not reported.

Supplemental Table 3. Data collected from studies evaluating marginal bone loss around implants with internal connections

Study	Type of Connection	Average (±SD) age	Males/ Females	Number of Smokers (>10 Cigarettes/D)	Number of Implants	Diameter/ length (mm)	Arch	Mfr	Prosthesis type	Prosthesis retention	Mean Bone Loss (±SD) (mm)/ Follow-up Period (mo)
Chou et al[2] 2004	Internal: Morse taper	NR	NR	NR	1500	NR	Maxilla and mandible	Ankylos-Dentsply	Single crowns, fixed partial prosthesis or full-arch prosthesis	NR	0.64/36
Pieri et al[19] 2011	Internal Morse taper (platform switching)	45.8	7/13	18	20	NR	Maxilla	NR	All-ceramic or metal-ceramic crowns	Cemented	0.19 (±0.17)/12
	Internal NR (Without Platform Switching)	46.6	8/12	19	20	NR	Maxilla	NR	All-ceramic or metal-ceramic crowns	Cemented	0.49 (±0.25)/12
Gultekin et al[20] 2013	Internal Trichannel connection	41.3	5/20	0	50	At least 3.5 in diameter and 8 in length	Maxilla and mandible	Nobel Biocare	Metal-ceramic crowns	Cemented	0.83 (±0.16)/12
	Internal Morse taper			0	43	At least 3.5 in diameter and 8 in length	Maxilla and mandible	NR	Metal-ceramic crowns	Cemented	0.35 (±0.13)/12
Jo et al[12] 2014	Internal NR	56.4	15/9	NR	20 (inter-implant distance $\leq$ 3mm)	NR	Maxilla and mandible	NR	Fixed 2-unit prosthesis	NR	0.15 (±0.18)/12
					30 (inter-implant distance $\geq$3mm)	NR	Maxilla and mandible	NR	Fixed 2-unit prosthesis	NR	0.11 (±0.33) 12
Meyler et al[40] 2014	Internal: hexagon	48.7	9/11	0	54	3.8, 4.5 and 5.5/10, 11, 13 and 15	Maxilla and mandible	Dentsply	Single crowns	Cemented	0.63 (±0.26) (Mesial site) 0.56 (±0.25) (Distal site) 120
Calvo-Guirado et al[5] 2014	Internal: NR	37.85 ±7.09	30/23	NR	71	4.2 and 5/11.5 and 13	Maxilla	MIS-Implants	Single crowns	NR	0.86 (±0.29)/36

NR, not reported.

Supplemental Table 4. Marginal bone loss for each period evaluated by studies

			Mean Bone Loss (±SD) in mm for the Period Shown (mo)								
Study	**Type of Connection**	**Mean Bone Loss (±SD) in mm Between Implant Installation to Prosthesis Installation**	**3**	**4**	**6**	**12**	**18**	**24**	**36**	**60**	**120**
Chou et al[2] 2004	Internal: Morse taper	0.81	-	-	-	0.15	-	0.48	0.64	-	-
Kielbassa et al[17] 2009; Arnhart et al[18] 2012	Internal: Morse taper with antirotational mechanism	NR	-	-	-	0.95 (±1.37)	-	-	0.89 (±1.65)	-	-
	External: Transmucosal implant with antirotational mechanism	NR	-	-	-	0.64 (±0.97)	-	-	0.16 (±1.06)	-	-
	Internal: Morse taper	NR	-	-	-	0.63 (±1.17)	-	-	0.85 (±1.32)	-	-
Crespi et al[15] 2009	External: hexagon	Immediate loading	-	-	-	0.82 (±0.40)	-	0.78 (±0.49)	-	-	-
	Internal: Morse taper	Immediate loading	-	-	-	0.78 (±0.45)	-	0.73 (±0.52)	-	-	-
Pieri et al[19] 2011	Internal: Morse taper	Immediate loading	-	0.08 (±0.1)	-	0.19 (±0.17)	-	-	-	-	-
	Internal: NR	Immediate loading	-	0.22 (±0.16)	-	0.49 (±±0.25)	-	-	-	-	-
Peñarrocha-Diago et al[14] 2013	Internal: Morse taper	0.05 (0.11)	-	-	0.07 (0.13)	0.12 (±0.17)	-	-	-	-	-
	External: hexagon	0.16 (0.31)	-	-	0.27 (0.43)	0.38 (0.51)	-	-	-	-	-
Koo et al[7] 2012	External: hexagon	0.61 (0.37)	-	-	-	0.29 (0.35)	-	-	-	-	-
	Internal: octagon	0.08 (0.30)	-	-	-	-0.07 (0.21)	-	-	-	-	-
Vandeweghe and De Bruyn[6] 2012	External: hexagon with platform switching	Immediate loading	0.28 (±0.3)	-	0.64 (±0.63)	0.66 (±0.47)	-	-	-	-	-
	External: hexagon without platform switching	Immediate loading	0.51 (±0.4)	-	1.05 (±0.61)	0.94 (±0.42)	-	-	-	-	-
Canullo et al[8] 2012	External: hexagon	NR	-	-	~1.0	~1.45	1.63	-	-	-	-
	Internal: inward-inclined platform	NR	-	-	~0.25	~0.35	0.49	-	-	-	-
Lin et al[16] 2013	External: hexagon	0.45 (±0.19)	0.21 (±0.13)	-	0.32 (±0.19)	-	-	-	-	-	-
	Internal: Morse taper	0.38 (±0.19)	0.19 (±0.11)	-	0.32 (±0.14)	-	-	-	-	-	-
	Internal: octagon	0.44 (±0.15)	0.18 (±0.12)	-	0.38 (±0.22)	-	-	-	-	-	-
Gultekin et al[20] 2013	Internal: trichannel connection	0.24 (±0.14)	-	-	-	0.83 (±0.16)	-	-	-	-	-
	Internal: Morse taper	0.22 (±0.11)	-	-	-	0.35 (±0.13)	-	-	-	-	-
Pozzi et al[4,13] 2014	Internal: Morse taper	0.37 (±0.23)	-	-	-	0.51 (±0.34)	-	-	0.67 (±0.39)	-	-

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Supplemental Table 4. (*Continued*) Marginal bone loss for each period evaluated by studies

Study	Type of Connection	Mean Bone Loss (±SD) in mm Between Implant Installation to Prosthesis Installation	Mean Bone Loss (±SD) in mm for the Period Shown (mo)								
			3	4	6	12	18	24	36	60	120
	External: hexagon	0.95 (±0.56)	-	-	-	1.10 (±0.52)	-	-	1.24 (±0.47)	-	-
Calvo-Guirado et al[5] 2014	Internal: NR	Immediate loading	-	-	-	0.67 (±0.21)	-	0.79 (±0.23)	0.86 (±0.29)	-	-
Meyle et al[40] 2014	Internal: hexagon	Immediate loading	-	-	-	-	-	-	-	0.16 (±0.1) (mesial site) 0.23 (±0.34) (distal site)	0.63 (±0.26) (mesial site) 0.56 (±0.25) (distal site)

NR, not reported.