



Bone loss-related factors in tissue and bone level dental implants: a systematic review of clinical trials

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Abstract (J Korean Assoc Oral Maxillofac Surg 2021;47:153-174)

Dental implants are popular for dental rehabilitation after tooth loss. The goal of this systematic review was to assess bone changes around bone-level and tissue-level implants and the possible causes. Electronic searches of PubMed, Google Scholar, Scopus, and Web of Science, and a hand search limited to English language clinical trials were performed according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines up to September 2020. Studies that stated the type of implants used, and that reported bone-level changes after insertion met the inclusion criteria. The risk of bias was also evaluated. A total of 38 studies were included. Eighteen studies only used bone-level implants, 10 utilized tissue-level designs and 10 observed bone-level changes in both types of implants. Based on bias assessments, evaluating the risk of bias was not applicable in most studies. There are vast differences in methodologies, follow-ups, and multifactorial characteristics of bone loss around implants, which makes direct comparison impossible. Therefore, further well-structured studies are needed.

Key words: Alveolar bone loss, Bone-implant interface, Bone resorption, Dental implants, Dental implant-abutment design

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I. Introduction

Bone loss following tooth extraction is an important issue that requires rehabilitation^{1,4}. Treatments such as removable or fixed prostheses do not typically provide satisfactory functional and aesthetic outcomes¹. Endosseous implants with predictable long-term success rates (SCRs) have become popular in overcoming the limitations of conventional treatments and improving the quality of life^{1,3,5}.

Survival and SCRs of implants are related to surrounding bone quality, quantity, and preoperative mucosal tissue

characteristics^{2,6}. Patient age, oral hygiene, presence of dental plaque and microorganisms, implant location and features, surgical procedure, and prosthesis type are statistically significant factors for SCR⁷. Moreover, marginal bone around implants is affected by various factors including smoking, periodontal disease, socket condition, healing after insertion, and implant abutment microgaps⁸.

Many studies have analyzed ways to improve implant features since the macrostructure, microstructure, and bio-mechanical design of implants affect marginal bone-level changes and subsequent tissue interactions^{1,2,4}. Roughened hydrophilic implant surfaces enhance bone healing, osteogenesis, and bone-implant contact (BIC) by accelerating cell migration, proliferation, and differentiation^{4,9,10}. SLActive surfaces have been created by coarse grit blasting and acid etching in order to promote fatigue strength with the mechanism of stabilizing blood clots in the defect area without affecting osseointegration^{1,4,11}.

Two types of implants have been introduced based on their macrostructure characteristics: bone-level (BL) and tissue-level (TL). BL types are placed with the neck of the implant

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at the level of the crestal bone and can cause marginal bone loss (MBL) following bacterial contamination or inflammation^{12,13}. Therefore, the TL design has been proposed to eliminate inflammation and subsequent bone loss. However, it may cause a gray metallic shadow through the soft tissue because of the metallic tulip-shaped shoulder^{12,13}. BL implants are the implant of choice in esthetic areas since they can be placed more apically and create a desired emergence profile^{14,15}. It has been reported that SLActive BL implants induce bone apposition⁴.

Implants are designed to be used as a one-piece or two-piece instrument. More crestal bone loss in two-piece implants may be due to microgaps at the implant-abutment interface for bacterial colonization of the implant sulcus or establishment of an adequate dimensioned biologic width (BW) to be associated with marginal bone resorption^{16,17}. The implant-abutment microgap is possibly related to the precision fit between the implant components subsequent to the implant system design and the torque used to connect the components¹⁷. Researchers have attempted to introduce designs to eliminate the microgaps¹⁸. The gaps and the following disadvantages have been diminished using TL implants^{12,13}. One-piece implants could provide a more effective seal against microbial leakage by reducing the size of the microgaps resulting in a reduction in inflammatory reactions around the implant-abutment interface and subsequent marginal bone resorption¹⁹. The abutment-fixture connection (AFC) is an important factor for the long-term stability of implants and hard and soft tissue due to the presence of microgaps^{14,20}. Therefore, the prevention of microbial leakage at the AFC is a major challenge for the construction of two-piece implant systems to minimize inflammatory reactions and to maximize peri-implant bone stability²¹.

The most common AFCs are external hexagonal, internal hexagonal, conical, and mixed^{17,21}. All the connections exhibit a certain amount of microgaps and bacterial microleakage, although fewer are seen in the conical and mixed connection systems²¹. The most favorable results have been reported when implants with an internal Morse-taper connection have been utilized, resulting in minimal bacterial leakage to the threaded aspect of the AFC. However, dynamic loading increases the potential for such bacterial penetration^{17,21}. Platform-switching has been introduced as a method to shift the stress inward and enhance hard tissue stability, papilla maintenance, and the soft tissue seal^{16,19,22-25}. A study reported 0.7 mm versus 2.5 mm bone loss compared to the conventional connection design after 6 months of loading while the other

design exhibited 0.12 mm versus 0.29 mm bone loss after one year¹⁶. Another assessment demonstrated no bone loss after 2 years¹⁶. Until now, no implant system or connection design has been able to provide a perfect outcome at the AFC.

Minimizing bone loss both horizontally and vertically around implants, which is essential for good aesthetic outcomes of implant treatment, has been the most challenging issue in implantology. Therefore, the aim of the present systematic review is to review and compare BL changes after the insertion of BL and TL designs of implants and assess factors affecting bone loss.

II. Materials and Methods

This systematic review was conducted according to the Cochrane Handbook PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines.

All clinical trials which focused on BL change after the placement of BL or TL implants were included. The search was limited to English-language studies up to September 2020. Abstracts, letters, and reviews were excluded.

Type of participants: Any humans with edentulous regions in one or both jaws with BL and TL implant placements were included. Studies which focused on the soft tissue, aesthetic results, or did not mention bone resorption for each kind of implant separately were excluded.

Type of interventions: Studies that had used one or more BL or TL implants were included. Studies were excluded if they had focused on biomechanical features or the survival rate (SVR) of implants or had evaluated implant stability and micromotions.

Type of outcome measures: BL changes after implant insertion were reported by measuring MBL (mm), mean bone fill (mm²), BIC (mm), new bone height (mm), and mean bone level (mm).

Information sources: Our electronic database consisted of PubMed/MEDLINE, Google Scholar, Scopus, and Web of Science. Additionally, a hand search was performed to assess publications that were not electronically distinguished.

Search strategy: An electronic search was performed in order to select relevant studies using the following terms: “bone level implant”, “tissue level implant”, “bone level implant” AND/OR “tissue level implant”, “bone/tissue level implant” AND “marginal bone loss”, “bone/tissue level implant” AND “bone resorption”, and “bone/tissue level implant” AND “marginal bone level change”.

Study selection: Two independent authors conducted the

search based on the aforementioned keywords. In addition, they carried out the initial screening of titles and abstracts from selected studies in accordance with the eligibility criteria. Any disagreement between the authors was resolved following a discussion with the third author (periodontist).

Data collection process: Review and data extraction were performed according to the PRISMA flow diagrams. Two authors also reviewed full texts of the articles and extracted all the data independently.

Data items: Results and data extracted from the included studies were classified in tables with the following columns: study type, study design, implant placement area, bone results, non-related bone results, measurement device, defect model, and follow-up. (Tables 1-3)

Risk of bias assessment: The criteria used for assessing the quality of the included studies was obtained from the Cochrane Center. The provided guidelines consisted of the following parameters: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data addressed, and selective reporting. The degree of bias was categorized as low risk, unclear risk, and high risk. The risk of bias was evaluated independently by two masked reviewers. All disagreements were resolved by consensus.

III. Results

After the initial search, 173 articles were obtained. Following the removal of duplicates and irrelevant studies, a total of 97 studies were selected. Full texts of the selected articles were screened and with respect to eligibility criteria, 59 studies that either were *in vivo* or had focused on soft tissue results, biomechanical features, or implant stability with no bone-related reports were excluded. Finally, 38 articles were included in our systematic review. (Fig. 1) Data were extracted and further classified in three separate tables. (Tables 1-3) Table 1 consists of 18 studies that used only BL implants and 10 articles that used TL implants were placed in Table 2. Table 3 comprises 10 studies that compared BL change results of both BL and TL implants.

Patient sex, age, and number: Among the included studies, 10 did not mention patient sex^{1,10,22,23,26-31}. Between all the studies mentioning mean age, maximum mean ages in Tables 1-3 were 65.8¹, 54.63³², and 60³⁰, respectively, while minimum amounts were 33²⁴, 36²⁸, and 39³³ in order.

Comparing patient numbers in the studies, the highest number of patients in a single study was 881²⁵ with the lowest

being 13 in another study^{10,31}. Only 2 studies did not indicate the number of patients^{22,28}.

Implant numbers: Various implant numbers were reported. The highest and lowest implant numbers used in the studies were 908¹³ and 16⁹ in Table 1, 1,692²⁵ and 16³⁴ in Table 2, and 337²⁹ and 32³¹ in Table 3, respectively.

Study design: Various methodologies had been used in the included articles. Seven studies utilized implants with SLActive surfaces^{1,9,10,13,22,28,35}, while 7 studies focused on the platform switched implants effects^{5,23,24,36-39}. Two articles inserted implants with both mentioned characteristics^{15,19}.

Seven studies applied grafts in their surgical procedures^{2,16,40} in which 4 of them indicated the use of autogenous bone grafts^{5,15,41,42}. In addition, 10 studies mentioned guided bone regeneration (GBR) in their methods^{3,8,9,19,20,25,26,43-45}.

Implant placement areas: In 10 articles, implants were inserted in the maxilla^{10,15,16,19,23,24,33,34,43,45}, while 4 studies chose the mandible as the placement area^{1,6,28,31}. In 22 studies, implants were inserted in both jaws^{2,3,5,8,13,20,25-27,29,30,32,35-42,44,46}. Two studies did not state which jaw was used^{9,22}.

Measurement devices: The majority of studies used only periapical radiographs to estimate bone resorption around the implants^{3,6,9,13,15,16,19,22,27,33-37,39,43}. Four studies utilized cone-beam computed tomography (CBCT) images^{10,28,29,44}, while 3 studies used panoramic images^{1,32,42}. A combination of panoramic plus periapical images and CBCT plus periapical images were used in 6 studies^{2,5,24,25,30,40} and 4 studies^{31,38,45,47}, respectively. One article evaluated MBL through the help of CBCTs, panoramics, and periapical images⁸, while another used panoramics, periapicals, and computed tomography (CT) scan images⁵. One study reported a radiological device to measure bone levels, but did not provide specifics²⁰. Only one study used a morphometric method²⁶, while one did not mention the measurement device²³.

Follow-ups: Follow-up duration varied widely. In Table 1, the shortest and the longest follow-ups were one month⁴³ and 5 years⁸, respectively; in Table 2, these values were 3 months²⁸ and 15 years³², respectively. The longest period of follow-up was 7.8 years³³, while the shortest period was 3 months³¹ among the studies that used both BL and TL implants.

Bone results: Bone status after implant insertion varied. A large number of studies indicated bone loss^{5,6,16,19,20,22,24,25,27,33,39,40-43}. MBL and BL changes were presented in 13 studies^{2,5,8,15,24,25,28-31,36,38,47} and 11 studies^{1,3,9,15,22,23,32,34,37,42,45}, respectively. Other bone results involved reports of BIC³⁶ and distances from implant shoulder

Table 1. Studies on inserted BL implants

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Andreasi Bassi et al. ² (2016)	Prospective	52	Cylindrical & tapered Internal hexagonal Bone graft SLActive	Max/Man Ant/Post	Mean MBL: 77% Mean peri-implant bone loss: 0 mm	SVR: 100% Worse results only in implant supporting bridges.	Panoramic PA	21 F/31 M Mean age: 54	44.6 mo (mean)
Filippi et al. ¹³ (2013)	Prospective multicenter non-interventional	908	Max/Man Ant/Post	Max/Man Ant/Post	No change in crestal BL (62.2% & 61.8% mesial & distal) BL change >1 mm in <5% of implants (4.5% & 3.9% mesial & distal) Bone growth around 3% of cases (3.3% & 3% mesial & distal)	SVR: 98.5% SCR: 96%	PA	852 (55.6% F/44.2% M) Mean age: 53.7	1, 2 & 3 yr
Wu et al. ⁸ (2018)	Retrospective	114	Internal hexagonal Fresh socket GBR (30 patients) A: submerged B: nonsubmerged	Max/Man Ant/Post	No differences in MBL Mean MBL: 1st yr (majority of MBL): A: 1.20 mm B: 1.17 mm 5th yr: A: 1.98 mm B: 1.94 mm Mean MBL <1.5 mm within the 1st yr Mean MBL between 1 & 5 yr: A: 0.78 mm B: 0.77 mm	SVR: A: 94% B: 96% No difference in failure time. Implants with a diameter of 3.0 mm: lower SVR	CBCT Panoramic PA	42 M/30 F 55 patients <60 yr, 17 patients >60 yr	Annually for 5 yr
Ghazal et al. ³ (2019)	Prospective RCT	47	TiZr SLActive T: narrow (3.3 mm) C: standard diameter (4.1 mm)	Max/Man Ant/premolar	Mean BL change: 6 mo: similar 12 mo: T: -0.27 mm C: -0.48 mm	SCR & SVR: 100% No differences in gingival recession & patient satisfaction.	PA	50 (M 36%/F 64%) Mean age: 51.2	6 & 12 mo Postloading
Lorenz et al. ²⁰ (2017)	Retrospective follow-up	47	GBR (synthetic bone graft: HA & β-TCP)	Max/Man	Mean bone loss: 0.55 mm (range, 0-3 mm)	Low median rates for PD (2.7 mm) & BOP (30%) Mean PES: 10.1 from 14.	Radiological	11 F/9 M Mean age: 58.5	36-48 mo Postloading Mean: 42.6 mo

Table 1. Continued

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Lago et al. ³⁶ (2017)	Prospective clinical	67	Platform switched	Max/Man Post (premolar)	Mean MBL: Baseline to 1 yr: 0.06 mm 1 to 5 yr: 0.23 mm Baseline to 5 yr: 0.28 mm No difference from baseline to 1 yr. BIC: Baseline: 0.64 mm 1 yr: 0.59 mm 5 yr: 0.35 mm 12 mo: Mean bone loss: 0.18 mm (1 implant with bone loss >0.5 mm & 15 with minimal bone loss [< 0.25 mm]) Mean DIB: 3 mo: 0.09 mm 6 mo: 0.14 mm 12 mo: 0.18 mm 18 mo: Mean BL change: -0.10 mm No differences between A & B.	Soft tissue: Papilla tip to contact point distance: Baseline: 2.08 mm 1 yr: 1.54 mm 5 yr: 1.31 mm Difference between 1 & 5 yr & baseline & 5 yr No difference in buccal margin.	PA	20 M/15 F Mean: 47.1	1 & 5 yr
Buser et al. ⁴³ (2009)	Prospective case series	20	Sand-blasted & acid-etched surface GBR	Max Ant (single tooth)		12 mo: Mean: PI: 0.36 SBI: 0.26 PD: 4.43 mm Facial DIM: -3.53 mm No severe recession (1 mm)	PA	5 M/15 F Mean age: 41.7	1, 3, 6, 12 mo
Santing et al. ²³ (2013)	Prospective cohort	60	Platform-switched A: augmented B: non-augmented	Max Ant (single tooth)		Mean PD: 2.57 mm ICAI & PES: Less favorable in A.	NM	60 >18 yr	7 & 18 mo
Gao et al. ¹⁵ (2017)	Open-label single-arm observational	22	Platform switched & SLActive +autogenous bone	Max Ant (single tooth) position: 14-24	MBL: Most implants (95.5%) <0.5 mm & one (4.5%) with 2.12 mm change from baseline to 36 mo (mean, 0.07 mo) Crestal BL decreased, from 2.34 mm at baseline to 1.70 mm at 36 mo.	SCR: 100% SVR: 100% Functional SCR: 95.5% Increase in mean stability from provisional & final prosthesis. Facial gingival margin & papilla: stable Mean PD: 12 mo: 1.26 mm 24 mo: 1.02 mm 36 mo: 1.40 mm	PA	8 M/13 F Mean: 44.97	6, 12, 24, 36 mo

Table 1. Continued

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Flores-Guillen et al. ¹⁹ (2018)	Prospective RCT	30	SLActive Platform switched A: Submerged B: Transmucosal +GBR	Max Ant Non-molar sites (single tooth)	Mean bone loss: A: 0.59 mm B: 0.78 mm Similar bone gain after 1 yr. 5 yr: Bone loss of <1 mm in 76.7% of implants. A: greater bone loss for 1 yr (0.73 mm) than 1-5 yr (-0.10 mm) B: 0.73 mm (1 yr) & 0.04 mm (1-5 yr)	SVR: 100% Peri-implantitis (crestal BL \geq 2 mm) & BOP only in one patient. Similar responses with significant increase in PI in mesial & distal papillae.	PA	23 M (57.5%) 17 F (42.5%) Mean age: 48.5	1, 2, 3, 4, 5 yr
Vanhoğlu et al. ²⁴ (2014)	Clinical trial	55	Platform switched	Max Ant (single tooth) (central to premolar)	Successful integration of all. MBL <0.5 mm for all. Mean bone loss at final recall: 0.12 mm (No significant difference) No difference in MBL in Zr & Ti abutments. 7 implants with increase in level of bone contact. MBL: Baseline: 0.08 mm 1 yr: 0.1 mm 2, 3, 4 yr: 0.12 mm	SVR: 100% Complete papilla fill in 89.09% Mean PD: Baseline: 2.1 mm 2, 3 yr: 2.2 mm 4 yr: 1.9 mm	Panoramic PA	23 F/24 M Mean: 33	2, 3, 4 yr
Chiapasco et al. ⁵ (2012)	Clinical trial	60	Platform switched Autogenous cortical grafts from ramus or calvarium	Max/Man (post & partial edentulous vertical & horizontal defects)	Mean bone loss before implantation: 0.18 mm (calvarial grafts) 0.42 mm (ramus grafts) Mean MBL after implantation: 0.41 mm (calvarial grafts; mostly 0 mm) 0.52 mm (ramus grafts; mostly 0-1 mm)	SVR: 100% for both groups SCR: 90.3% in calvarial graft 93.1% in ramus grafts	Panoramic PA CT	12 F/6 M 18 to 69 yr Mean: 49.1	12-36 mo post loading Mean: 19 mo

Table 1. Continued

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Donos et al. ⁹ (2019)	Prospective, single blind RCT	16	SLActive T: Immediately provisiona- lized with non-occluding temporary crown C: Left without a crown+GBR	Esthetic area Ant/ premolar (single tooth)	Mean BL change from baseline: T: 12 mo: -0.62 mm (peak of bone loss) 36 mo: -0.42 mm 48 mo: -0.41 mm 60 mo: -0.42 mm C: 12 mo: -0.18 mm 36 mo: -0.10 mm 48 mo: -0.24 mm 60 mo: -0.37 mm 60 mo: similar bone loss.	SVR: 100% SCR: C: 77.8% (36 mo), 88.9% (48 mo) & 66.7% (60 mo) Mean PD changes: T: Only limited changes C: more pronounced changes, more improvements in PES, soft tissue contour & mesial papilla Largest differences in PD change: 48 mo (T: 0.9 mm, C: 1.6 mm) & 60 mo (T: 1.43 mm, C: 2.2 mm). SCR: 100% Stability at baseline: 71.7 (increased to 1 yr [80.3], except at 2 wk with a nonsignificant decrease [71.9]) No BOP PD <3 mm	PA	5 M/11 F Mean: 48.9 (T) & 49.6 (C)	36, 48 & 60 mo
Marković et al. ¹⁰ (2015)	Prospective Clinical	37	SLActive	Max Post	Continuous & significant bone loss: 0.4 mm 0.5 mm or higher around 2 implants		CBCT	13 Mean age: 47.1	1 yr
Canullo et al. ¹⁶ (2010)	RCT	69	Platform diameters: C: 3.8 mm T1: 4.3 mm T2: 4.8 mm T3: 5.5 mm +bone substitute	Max Post	Inverse correlation between the extent of mismatching & amount of bone loss. Inverse correlation between MBL & abutment-implant diameter. Mean bone loss: 21 mo: C: 1.49 mm T1: 0.99 mm T2: 0.82 mm T3: 0.56 mm 33 mo: No difference with 21 mo data except for T2 (0.87 mm) & T3 (0.64 mm).		PA	17 M/14 F Mean age: 52.1	9, 15, 21, 33 mo
Al-Nawas et al. ¹ (2012)	Double blind, prospective RCT	178	A: Ti13Zr B: Ti Grade IV small- diameter, SLActive Overdenture (No graft)	Man (interfora- minal region)	6 mo: most BL changes: A: -0.23 mm B: -0.23 mm 12 mo: A: -0.34 mm B: -0.31 mm	No differences in PI & SBI. 12 mo: SVR: 98.9% (A) & 97.8% (B) SCR: 96.6% (A) & 94.4% (B)	Panoramic	91 Mean age: 65.8	6 & 12 mo

Table 1. Continued

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Puisys and Linkevicius ⁶ (2015)	Prospective controlled clinical trial	97	Vertical gingival thickness: T1: thin, 2 mm or less T2: thin thickened with allogenic membrane C: thick, >2 mm	Man Post	Bone loss: 2 mo: T1: 0.75 mm mesially & 0.73 mm distally. T2: 0.16 mm mesially & 0.2 mm distally. C: 0.17 mm mesially & 0.18 mm distally. 1 yr: T1: 1.22 mm mesially & 1.14 mm distally. T2: 0.24 mm mesially & 0.19 mm distally. C: 0.22 mm mesially & 0.20 mm distally. Significant differences between T1/T2 & T1/C mesially & distally.	SVR: 100%	PA	28 M/69 F Mean age: 47.3	2 mo Postloading & 1 yr
Nóvoa et al. ²² (2017)	Clinical trial	60	SLActive Abutment heights: C: 1 mm T: 2.5 mm	NM	Bone loss up to: C: 1.3 mm T: 0.33 mm Mean BL change: 1 yr: C: 0.82 mm T: 0.2 mm 2 yr: C: 1.27 mm T: 0.22 mm 3 yr: C: 1.23 mm T: 0.35 mm	-	PA	-	1, 2 & 3 yr

(BL: bone level, Max: maxilla, Man: mandible, Ant: anterior, Post: posterior, MBL: marginal bone loss, SVR: survival rate, PA: periapical, F: female, M: male, SCR: success rate, GBR: guided bone regeneration, CBCT: cone-beam computed tomography, RCT: randomized clinical trial, HA: hydroxyapatite, b-TCP: beta-tricalcium phosphate, T: test, C: control, PD: probing depth, BOP: bleeding on probing, BIC: bone-implant contact, PES: pink esthetic score, SBI: sulcus bleeding index, DIM: distance from the mucosal margin to the implant shoulder, ICAI: implant crown aesthetic index, NM: not mentioned, Ti13Zr: Titanium13 Zirconium, DIB: distance from implant shoulder to the first BIC, PI: plaque index)
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Table 2. Studies on inserted TL implants

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Kang et al. ²⁵ (2018)	Retrospective radiographic observational	1,692	GBR in 7.7% Sinus graft in 6.7%	Max/Man Ant/Post	Overall bone loss: 3 yr: 0.07 mm 5 yr: 0.09 mm 7 yr: 0.14 mm 9 yr: 0.17 mm 14 implants with pathologic MBL >2 mm. 2 implants were removed with progressive MBL (5.5 & 7.5 yr). 5 implants showed early bone loss >1 mm within 1st yr but then showed a stable MBL. In 7 implants, bone loss started after 1st yr & progressed continuously. Implant diameter affected MBL. >99% of implants showed <1 mm bone loss in 3 yr, 1.9% >1 mm bone loss. Implants with >3 mm bone loss: only after 5 yr. Sufficient BV in 70% of implant sites. 17.6% of implants had insufficient crest width. Mean DIB: 3.32 mm DIB: 49.5%: between 2.51 & 3.50 mm (no or minimal bone loss). 11.3% <2.5 mm (no bone loss or gain). 34.9%: between 3.51 & 4.5 mm (moderate bone loss). 4.4% >4.51 mm. Latter two subgroups: narrow radiolucent gap along implant surface in crest.	SVR: 98.2%	Panoramic PA	881 (496 M/385 F) Mean age: 52.2	10 yr Mean: 5.3 yr
Buser et al. ³⁵ (2012)	Retrospective	511	SLActive	Max/Man Ant/Post Partially edentulous		SVR: 98.8% SCR: 97.0% Mean PI: 0.65 Mean PD: 3.27 mm Mean SBI: 1.32 Mean DIM: -0.42 mm.	PA	303 (160 F, 52.8%/143 M, 47.2%) Mean age: 48	10 yr

Table 2. Continued

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Friedmann et al. ²⁶ (2011)	Randomised controlled, single-blinded pilot clinical trial	73	Lateral augmentation & GBR Biphasic CaP+ membranes: T: ribose cross linked coll membranes C: non-cross-linked mem branes	Max/Man Ant/Post	Gain in clinically hard MT at crestal level: T (lateral defects): 1.8 mm C (lateral defects): 0.7 mm T (vertical defects): 1.1 mm C (vertical defects): 0.2 mm Second measurement: Lateral defects: (median width gain): T: 3.0 mm C: 2.1 mm (median vertical gain): T: 2.5 mm C: 2.7 mm	SVR: 100% Soft tissue dehiscences at 70.5% & 55% frequency for T & C	Morphometric	37 Mean: 53	6 mo
Ladwein et al. ³² (2015)	Clinical cross-sectional analysis	967	A: NKM B: KM	Max/Man Ant/Post	No difference in vertical BL. Of Post implants, 40.3% showed NKM. Of Ant implants, 30.4% showed NKM.	Mean KM width: 1.87 mm. A: more PI & SBI No difference in PD: PD mesial A: 3.78 mm B: 3.61 mm SVR: 98.1%	Panoramic	211 (97 M/114 F) Mean: 54.63 (maximum:78)	Mean: 7.78 yr (4-15 yr)
Le and Borzabadi-Farahani ⁴⁴ (2014)	Clinical trial	156	Transmucosal implant/ Simultaneous GBR (allograft) Vertical defect: A: small (<3 mm) B: medium (3-5 mm) C: large (>5 mm)	Max/Man Post Localized buccal wall of bone defects	Significant differences in simultaneous grafting with different pre-treatment vertical defect sizes. Two graft failures (one needed re-grafting) & 2 implant failures. Complete correction of 100% & 79.3% of A & B. C: only partial improvement in 90% of cases, without any complete correction.		CBCT	108 (38 M/70 F) Mean: 46.7	36 mo

Table 2. Continued

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Fretwurst et al. ⁴² (2015)	Retrospective	150	Onlay graft (anterior superior iliac crest)	Max/Man Partially edentulous/edentulous with severe alveolar ridge resorption & remaining BV of <5 mm in height	Mean crestal bone loss: 10 yr: 1.8 mm (>5 mm increase). Significant difference between sex & crestal bone loss, but no influence of implant system, diameter, & patient age. 10 yr mean BL change: F: 2 mm (range, 0.5-4 mm) M: 1 mm (range, 0.5-2 mm) Mean bone loss (total) (significant difference): A: 0.29 mm B: 0.6 mm Mesial areas (No significant difference): A: 33.3% (0.32 mm) B: 47.6% (0.42 mm) Distal areas (significant difference): A: 38.1% (0.26 mm) B: 66.7% (0.78 mm) Mean bone loss: Man (significant difference): A: 0.19 mm B: 0.72 mm Max (similar) A: 0.36 mm B: 0.51 mm A: Same bone loss in both jaws regardless of areas.	SVR: Max: 96% Man: 92% Total: 95%	Panoramic	32 (22 F/10 M) Mean age: 52	Mean: 69 mo (range, 12-165 mo) (Graphy at 1, 3, 5, 10 yr)
Agustín-Panadero et al. ²⁷ (2019)	Prospective observational	42	A: convergent transmucosal collar B: divergent collar	Max/Man Post (molar & premolar)		-	PA	21	2 yr Postloading

Table 2. Continued

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Buser et al. ⁴⁵ (2013)	Prospective, cross-sectional	41	GBR	Max Ant (central to premolar) (single tooth)	PA: Stable peri-implant BL & mean DIB: 2.18 mm. CBCT: mean thickness of facial bony wall: 2.2 mm & mean thickness from 1.58 to 2.33 mm. 85% of implants: bone loss or bone gain within -0.8 & 0.8 mm. 4.9% of implants had no facial bony wall. Mean BL change: 0.071 mm	Mean PES: 7.49 Mean WES (more stable than PES): 6.88 Mean PD: 4.26 mm DIM: -3.42 mm (1st examination) & -2.21 mm (2nd examination) SVR: 100% PES (mean): Mesial papilla: 1.69 Distal papilla: 1.81 Total: 8.5	CBCT PA	41 (25 M/16 F) Mean age: 38.8	5 to 9 yr (mean: 7 yr)
Canullo et al. ³⁴ (2020)	Prospective	16	Convergent collar	Max Ant			PA	15 (11 M/4 F) Mean age: 54.6	3 yr
Makowiecki et al. ²⁸ (2017)	Comparative preliminary	30	T: short with hydrophilic surfaces C: SLActive (early & delayed loading)	Man Post	3 mo: Significant difference in primary stability & MBL. C (higher MBL): 0.53 mm T: 0.37 mm 6 mo: No significant difference in secondary stability. C: 0.57 mm T: 0.51 mm C: No differences in MBL between 3 & 6 mo.		CBCT	Mean age: T: 36 C: 45.5	12 & 24 wk

(TL: tissue-level, GBR: guided bone regeneration, Max: maxilla, Man: mandible, Ant: anterior, Post: posterior, MBL: marginal bone loss, SVR: survival rate, PA: periapical, M: male, F: female, BV: bone volume, DIB: distance from shoulder to the first bone-implant contact, SCR: success rate, PI: plaque index, PD: probing depth, SBI: sulcus bleeding index, DIM: distance from the mucosal margin to the implant shoulder, CaP: calcium-phosphate, T: test, C: control, MT: mineralized tissue, NKM: nonkeratinized mucosa, CBCT: cone beam computed tomography, BL: bone level, WES: white esthetic score, PES: pink esthetic score)

Hamed Mortazavi et al.: Bone loss-related factors in tissue and bone level dental implants: a systematic review of clinical trials. J Korean Assoc Oral Maxillofac Surg 2021

Table 3. Studies that inserted both BL & TL implants

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Kumar et al. ²⁹ (2014)	Retrospective clinical	337	BL: 179 TL: 158	Max/Man Ant/Post	12, 24, 36 mo: Mean MBL: BL: 0.3, 0.38, 0.48 mm TL: 0.6, 0.54, 0.9 mm No significant difference at 6-12 mo & slightly greater in TL. Deeper implants showed more bone loss. IDIP: BL: implant shoulder very near crestal bone (range, -0.71 to +0.78 mm; mean, +0.007 mm) TL: shoulder 0.43 to 2.73 mm above crestal bone margin (mean, 1.65 mm) Mean bone resorption: 0.52 mm (0-1 mm) in constructed areas 0.41 mm in calvarial grafts Mean bone resorption prior to implant placement: 0.18 mm for calvarial & 0.42 mm for ramus grafts	-	Panoramic	129	12, 24, & 36 mo
Chiapasco et al. ⁴¹ (2012)	Prospective	51	TL: 13 BL: 38 Autogenous vertical onlay grafts from calvarium or ramus	Max/Man Ant/Post (horizontally deficient edentulous ridge)	Mean bone resorption: 0.52 mm (0-1 mm) in constructed areas 0.41 mm in calvarial grafts Mean bone resorption prior to implant placement: 0.18 mm for calvarial & 0.42 mm for ramus grafts	SCR: 90.3% (calvarial grafts) 93.1% (ramus grafts) SVR: 100%	Panoramic PA	18 (6 M/12 F) Mean: 49.1	12-36 mo (mean, 19 mo)
Chiapasco et al. ⁴⁰ (2014)	Retrospective	192	TL: 97 BL: 95 Autogenous onlay grafts (ramus, iliac, calvaria)	Max/Man Ant/Post Vertical or 3D defects of edentulous ridges	Mean bone resorption: TL: 0.23 mm in ramus grafts, 0.36 mm in iliac grafts, 0.35 mm in calvarial grafts. BL: 0.48 mm in ramus grafts, 1.34 mm in iliac grafts, 0.35 mm in calvarial grafts	SVR: 100% SCR: 100% TL: 100% BL: 86.8% (93.5% in ramus grafts, 90.3% in calvarial grafts & 76.4% in iliac grafts) Overall complications: TL: 0% BL: 5.4%	Panoramic PA	50 (16 M/34 F) Mean age: 49.5	12-68 mo postloading (mean, 33 mo)

Table 3. Continued

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Lopez et al. ³⁰ (2016)	Retrospective cohort	150	Cylindrical 76 in F 74 in M GBR	Max/Man Ant/Post	Mean MBL: 92%. Mean bone loss: 0 mm Mean bone loss: BL: 0.12 mm TL: 0.04 mm Mean MBL up to 24 mo: TL: 0.75 mm BL: 0.70 mm	SVR: 98.7% SCR: 92%	Panoramic PA	Mean age: 60	Mean: 84 mo
Vianna et al. ⁴⁷ (2018)	Prospective, split-mouth RCT	40	TL: 20 BL: 20	Max/Man Ant/Post	Implant insertion: TL: 1.48 mm BL: 0.08 mm Prosthesis Installation: TL: 2.22 mm BL: 0.67 mm 6 mo: TL: 2.32 mm BL: 0.62 mm 24 mo: TL: 2.14 mm BL: 0.77 mm	No significant difference for PI & BOP. 80% of sites in both with at least one bleeding site at 12 mo & 90% at 24 mo. Similar PD	CBCT PA	20 (with history of chronic periodontitis) (6 M/14 F) Mean age: 49.13	Implant insertion, Prosthesis installation, 6 & 24 mm postloading
Fernández-Formoso et al. ³⁹ (2012)	RCT	114	TL: Standard matched BL: Platform switched	Max/Man Post	Mean bone loss (significant difference): BL: 0.01 mm TL: 0.42 mm Mean of DIB (significant difference between groups): TL: 0.42 mm (significant difference) BL: -0.01 mm (no significant difference)	-	PA	54 TL: 25 (16 F/9 M) Mean age: 43.7 BL: 26 (17 F/9 M) Mean age: 42.9	1 yr
Lago et al. ³⁸ (2018)	RCT	197	TL: Platform matched BL: Platform switched	Max/Man Post	Mean MBL: TL: Baseline to 1 yr: 0.26 mm 1 to 5 yr: 0.34 mm Baseline to 5 yr: 0.61 mm BL: Baseline to 1 yr: -0.03 mm 1 to 5 yr: -0.17 mm Baseline to 5 yr: -0.20 mm Significant difference between groups: Baseline to 1 yr: 0.31 mm 1 to 5 yr: 0.53 mm Baseline to 5 yr: 0.85 mm	SVR: TL: 1 yr: 100% 5 yr: 98% BL: 1 yr: 99% 5 yr: 96.1%	CBCT PA	54 M/46 F Mean age: 50.5 TL: 50 (31 M/19 F) Mean age: 47.9 BL: 50 (23 M/27 F) Mean age: 53.1	1 & 5 yr after definitive restoration

Table 3. Continued

Study	Study type	No. of implants	Study design	Implant placement area	Bone results	Other results	Measurement device	Sex & age (yr)	Follow-up
Lago et al. ³⁷ (2019)	Split-mouth RCT	100	TL: Platform matched BL: Platform switched	Max/Man Post	Crestal bone changes: Baseline to 3 yr: BL: 0.18 mm TL: 0.15 mm Mean: Baseline to 1 yr: 0.07 mm 1 to 3 yr: 0.01 mm Baseline to 3 yr: 0.04 mm Only significant difference in TL from baseline to 3 yr: 1-9 yr: BL: 14 implants with thick biotype & mean bone change of -0.03 mm & 8 with thin biotype & change of 0.09 mm. Total mean bone change: +0.02 mm 4-9 yr: TL: 12 implants with thick biotype & mean bone loss of 0.21 mm & 8 with thin biotype & mean bone loss of 0.05 mm.	-	PA	35 (15 M/20 F) Mean: 49.5	1 & 3 yr after definitive restoration
Wallner et al. ³³ (2018)	Clinical trial	42	TL: 20 BL: 22	Max Ant		-	PA	Human 41 (28 F/13 M) TL: mean age, 39 BL: mean age, 45	Mean: 4.9 yr (11 mo to 7.8 yr)
Hadzik et al. ³¹ (2017)	Comparative	32	Short implants BL: 16 TL: 16	Man (lateral aspect)	Total mean bone loss: 0.015 mm MBL: BL < TL 12 & 36 wk (significant difference in MBL): BL: Significant increase (0.19 & 0.29 mm or about 50%). TL: No significant changes (0.53 & 0.57 mm).	Primary stability: BL: 77.8 TL: 66.5 Secondary stability: BL: 78.9 TL: 73.9	PA CBCT	13 A: 7 (mean age, 45.9) B: 6 (mean age, 46.3)	12 & 36 wk

(BL: bone level, TL: tissue level, Max: maxilla, Man: mandible, Ant: anterior, Post: posterior, MBL: marginal bone loss, IDIP: initial depth of implant placement, SCR: success rate, SVR: survival rate, PA: periapical, M: male, F: female, GBR: guided bone regeneration, RCT: randomized clinical trial, PI: plaque index, BOP: bleeding on probing, PD: probing depth, CBCT: cone-beam computed tomography, DIB: distance from shoulder to the first bone-implant contact)

Hamed Montazavi et al: Bone loss-related factors in tissue and bone level dental implants: a systematic review of clinical trials. J Korean Assoc Oral Maxillofac Surg 2021

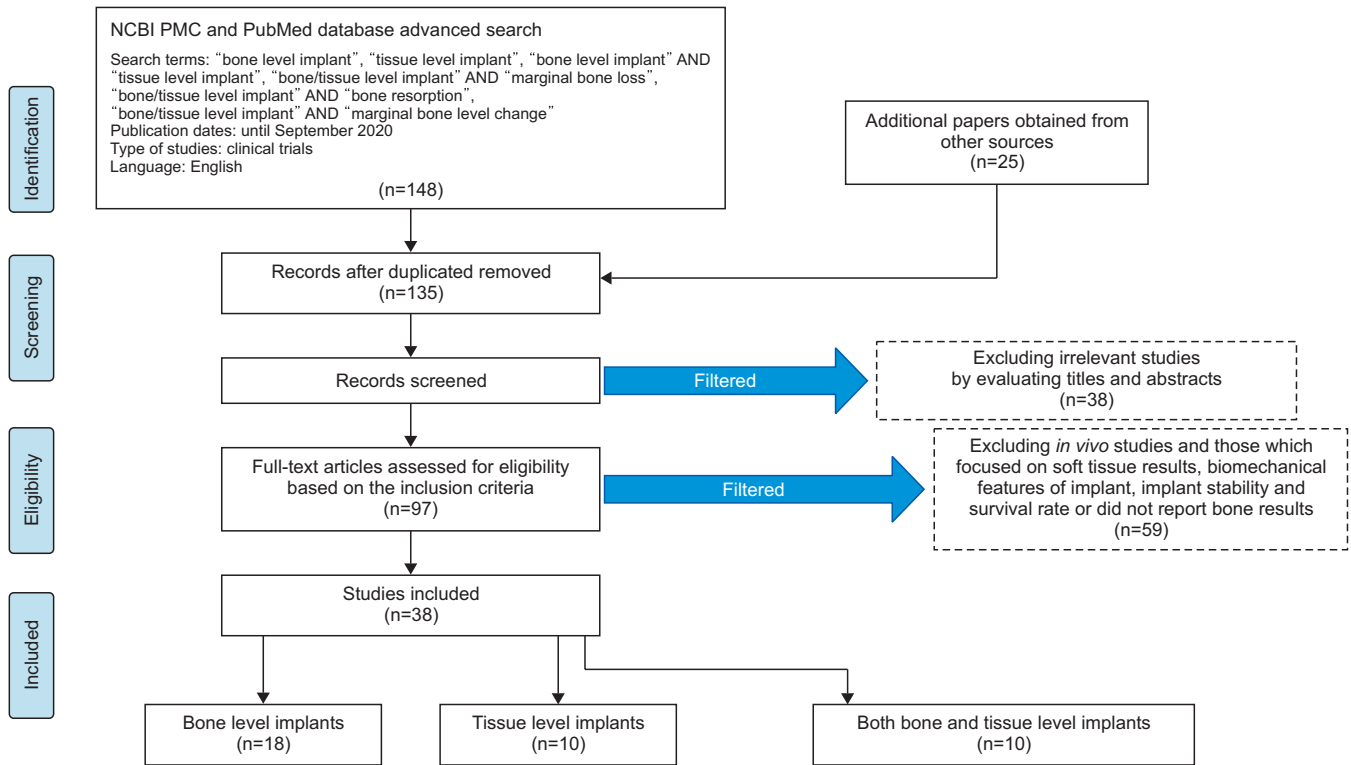


Fig. 1. Search strategy flowchart.

Hamed Mortazavi et al: Bone loss-related factors in tissue and bone level dental implants: a systematic review of clinical trials. J Korean Assoc Oral Maxillofac Surg 2021

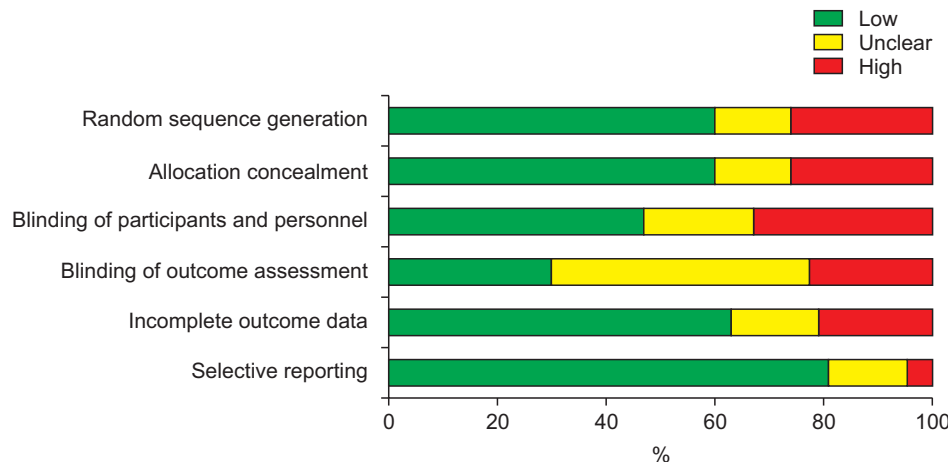


Fig. 2. Risk of bias assessment.

Hamed Mortazavi et al: Bone loss-related factors in tissue and bone level dental implants: a systematic review of clinical trials. J Korean Assoc Oral Maxillofac Surg 2021

to the first BIC (DIB)^{35,39,43,45}. Two studies reported both MBL and mean bone loss^{25,30}. In one article, hard mineralized tissue at the crestal level was evaluated¹²⁶, while another study reported the correction percentage of vertical defects after GBR and TL implant insertion⁴⁴.

Non-related bone results: Ten studies reported SVR^{2,6,8,19,24-26,36,42,44}, while one article mentioned only SCR¹⁰. Both SVR and SCR were reported in 10 studies^{1,3,5,9,13,15,30,35,40,41}. Other outcomes included reports of probing depths (PD) in 10 studies^{9,16,20,23,24,32,35,43,45,47}, plaque index (PI) in 4 studies^{1,32,35,43}, bleeding on probing (BOP) in 2 stud-

ies^{20,47}, and pink esthetic scores (PES) in 5 studies^{9,20,23,34,45}.

Risk of bias assessment: The evaluation of risk of bias is presented in Fig. 2 and 3. For 23 studies, randomization and blinding of participants, personnel, and outcome assessments were not applicable. Therefore, among 15 articles, 60%, 47%, and 30% of studies exhibited low risk in selection bias, performance bias, and detection bias, respectively. In relation to attrition bias and reporting bias, the majority of the studies showed no incomplete data or selective data reporting.(Fig. 2, 3)

IV. Discussion

Although implant placement is the preferred treatment method for tooth loss, the reason for MBL remains controversial. MBL induces pocket formation and affects peri-implant tissue health²⁴. In this review, parameters related to BL change after implant insertion are discussed in detail based on comparison of the included studies.

1. Patient-related factors

Individual differences: Significantly more MBL has been reported in females after 10 years, which may depend on differences such as factors influencing bone physiology and sex steroid hormones that provide harmony between bone formation and resorption with alterations in osteoclastogenesis and osteoblastogenesis⁴². Age and sex varieties may have an impact on autologous bone grafts⁴³. Other factors such as smoking, periodontitis, and infection in sockets should be excluded in order to increase the homogeneity and reliability of the results of the clinical trials⁸.

Bone quality and quantity: Implant insertion in severely resorbed ridges may lead to more failures². BL implants were successful in low-density bone after early loading protocols¹⁰. Interestingly, Marković et al.¹⁰ suggested that bone quality had no significant effect on the SVR of nonstructured and hydrophilic implants⁴⁸. Lower primary stability and higher secondary stability have been evidenced in bone with lower density. However, no significant difference in secondary stability was reported by Makowiecki et al.²⁸, which may be due to the differences in implant type and bone density. In their study, implants with more aggressive threads were inserted in bone type D1 as a study group and in bone type D2 as a control group. Maintaining a definite conclusion about the effect of bone density on implant stability remains difficult⁴⁸.

Soft tissue type and thickness: When the preoperative situation is compromised and the patient is realistic, the patient may be satisfied with the final result even when the outcome of an objective aesthetic index is poor²³.

Preoperative mucosal tissue thickness may be a major etiology in crestal bone loss⁶. According to Puisys and Linkevicius⁶, implant design and surface treatment does not have a significant impact on crestal bone levels if mucosal tissue is thin during implant insertion. Therefore, it can be hypothesized that when initial mucosal thickness is insufficient, BW with bone loss forms before loading. Therefore, a certain minimum width of peri-implant mucosa may be required^{6,22}.

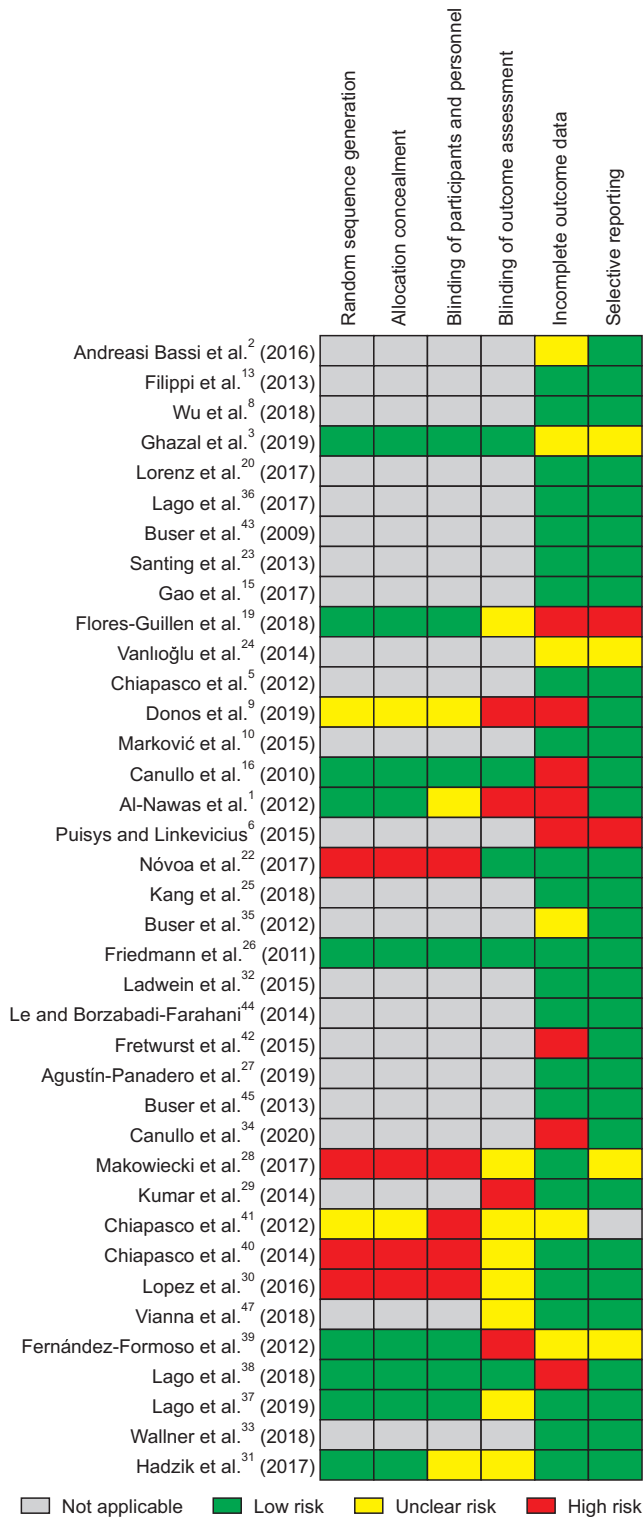


Fig. 3. Risk of bias assessment.
 Hamed Mortazavi et al: Bone loss-related factors in tissue and bone level dental implants: a systematic review of clinical trials. J Korean Assoc Oral Maxillofac Surg 2021

Although a high degree of satisfaction was observed in all subjects in whom allogenic membranes were used for vertical thickening of the soft tissues, thickened soft tissue may become thinner with time⁶. If mucosal tissue is ≤ 2 mm, significant bone loss may occur⁶. Soft tissues with thin biotypes exhibited more desirable outcomes even though thick, soft tissues have been more resistant to inflammation and trauma due to the different blood supply to the bone³³. It has been suggested that BL implants be used in areas with transparent soft tissue to obtain better esthetic results³³. Wallner et al.³³ reported negligible bone loss when a steady state has been achieved after the first phase of remodeling. They proposed that neither soft tissue type nor implant design affects peri-implant bone levels³³.

2. Implant-related factors

Implant type: BL implants provide more varieties of gingival formers during surgery with the margin of the abutment being adjusted at the time of prosthetic treatment⁸. In the study by Gao et al.¹⁵, after 6 weeks, surrounding bone loss was observed in all implants except for one that was placed above the alveolar crest shoulder. Interestingly, Gao et al.¹⁵ noticed not only <0.5 mm bone resorption at the crestal level of BL implants which was less than other reports, but also 3 cases with bone gain. Despite BL types which are placed at the crestal level with BW being set in a more apical position, TL implants reduce the recession of barrier epithelium and connective tissue depending on its position to the bone crest²². In addition, TL implants locate the AFC transmucosally, which demonstrates minimal bone alteration, but with compromising soft tissue esthetics because of the possibility of becoming visible. Therefore, BL implants are used more frequently in esthetic areas^{19,27}. On the other hand, TL implants with a convergent collar exhibited proper esthetic outcomes and stable hard and soft tissues during follow-ups in the anterior maxilla which can increase tissue thickness with being directly cemented on the implant neck and providing space for the connective tissue section of the supracrestal tissue attachment^{27,34}. Another advantage of the TL type is the ability to be detected easier during osseointegration with more favorable handling⁸.

Implant platform design: Crestal bone loss might be due to microgaps at the AFC for bacterial colonization of the implant sulcus or establishment of an adequate dimensioned BW to be associated with MBL at regions with a thin mucosa³⁴. This biological process is altered by repositioning

the outer edge of the AFC horizontally more inwardly and away from the outer edge of the implant platform leading to the introduction of the platform-switching design, in which a smaller-diameter prosthetic component is connected to a larger-diameter implant platform³⁹. The impact of platform switching on long-term crestal bone preservation remains controversial¹⁹. Canullo et al.¹⁶ introduced the relationship between platform switching design and the amount of MBL that could be attributed to a wider space for the horizontal repositioning of BW and/or a better distribution of loading stress at the BIC^{9,13,16,20}. The limitation of the study was that it only involved information on altering crestal mesial and distal bone loss especially vertically, not buccally and palatally¹⁶. Vanhooğlu et al.²⁴ demonstrated that BL implants with platform switching resulted in minimal bone resorption at the crestal level during functional loading. However, some implants exhibited an increase in bone height. On the other hand, BL implants with the platform switched design demonstrated a negative influence on crestal bone levels in comparison to TL implants⁴¹. Despite the evidence of higher crestal bone stability in platform switched BL implants by Fernández-Formoso et al.³⁹, higher SVR in TL implants with the platform matched design compared to platform switched BL implants was shown in another study (98% vs 96.1% after 5 years)^{39,49}. Comparing BL and TL implants with non-platform switched designs placed in the same graft type, similar SVR and peri-implant bone resorption were observed^{5,41}. Less MBL has been demonstrated in Astratech implants with platform switched designs compared to Straumann TL implants after 12 and 36 weeks³¹. Therefore, long-term studies evaluating the clinical efficacy of platform switched designs are still necessary^{23,33,36}.

3. Treatment procedure and follow-up related factors

Bone augmentation: The graft type seems to be the most important factor influencing graft resorption^{5,41}. More bone resorption has been shown in cancellous bone which could be harvested from the iliac^{5,41}. Demineralized bovine bone mineral (DBBM) granules will not be resorbed during the natural bone remodeling process and thus will help maintain the dimensions of the facial bone wall over time⁴⁵. Synthetic bone substitute material induced significantly higher vascularization than xenogenic bone, but after 6 months, new bone formation was not different⁵⁰. In the study performed by Le and Borzabadi-Farahani⁴⁴, mineralized allograft provided sufficient strength and shape in 61% of cases.

Similar implant stability and peri-implant bone changes were evidenced using the same BL implants (Astratech) with one study in fresh sockets and the other with GBR²⁰. Likewise, Fretwurst et al.⁴² found similar BL changes in implants placed in both augmented and non-augmented areas. Buser et al.⁴⁵ did not demonstrate change in DIB overtime and showed that GBR successfully established a facial bony wall in 95% of patients that was maintained for a mean of 7 years.

Less favorable esthetic outcomes were demonstrated in augmentation areas, which may be due to imperfect preoperative situations or the formation of scar tissue. However, no significant differences were reported in marginal BL change²³. Submerge techniques plus bone augmentation prevent overloading and bacterial contamination⁸.

Choosing the best alveolar bone grafting technique remains a challenge. Bone graft shrinkage may occur following remodeling. Therefore, it is advised to overcorrect the augmentation site and use a vertical incision in the flap to advance the flap coronally and support the graft⁴⁴. Grafting at the time of implant insertion reduces the number of invasive procedures and treatment time⁴⁴.

Location of the crestal portion of the implant: The crestal positioning of the implant's rough surface has been correlated with a greater maintenance of peri-implant bone compared to subcrestal positioning²². The supracrestal location of AFC limits bacterial access to the attachment and reduces the inflammatory response from bacterial contamination. Therefore, less MBL occurs during early phases^{16,27}. Kumar et al.²⁹ demonstrated more MBL in deeper implants, which may depend on more stress distribution on the crestal bone and greater distance of the inflammatory infiltrate to the crestal bone. It is possible to place TL implants at greater depth³³. On the other hand, less bone loss was reported in BL implants compared TL implants, but this was not significant, while in another study, significant lower MBL was observed in TL implants, which may be due to longer follow-up periods^{29,47}.

Implant placement protocol: MBL after surgical trauma is accepted particularly in the submerging protocol of BL implants¹⁵. Implants can be inserted in 3 ways: immediate, early, and late⁴³. Controversies exist in the hard and soft tissue results of immediate implant placement⁴³. Many immediate implants with recession have no facial bony wall in the long term, even though immediate placement is only recommended in patients with low risk factors in the placement area^{43,45}. Due to the lack of a facial bony wall around two implants, these two have no osseointegration in the facial aspect⁴⁵.

Loading protocol: Immediate placement containing func-

tional and non-functional (1 week), early (1-2 weeks), and conventional (more than 2 months) loading are known as the loading protocols^{9,24,43}. In contrast to previous studies, immediate loading exhibited a tendency for better long-term implant SCR^{9,51}. Even though nonfunctional loading helps diminish early overload, similar MBL and implant failure were reported between these two types of immediate loading^{9,24}. Successful functional early loading was reported without an increased risk of failure despite low bone density¹⁰. Early loading of platform switched BL implants is associated with minimal MBL and successful peri-implant mucosal architecture²⁴. It has been demonstrated that modified surface topography makes immediate or early loading possible even in areas of lower bone quality^{9,10}.

Radiography: Although radiography is the most widely used method to measure remaining bone height, distortion, superimposition, artefacts, and magnification are several known shortcomings^{27,52}. CBCTs offer excellent image quality with diminished radiation exposure compared to CT scans⁴⁵. Despite the proper accuracy of CBCTs in the presence of sufficient bone thickness, further studies are required to evaluate the accuracy in areas of insufficient bone⁵². Likewise, it has been demonstrated that CBCTs have low accuracy in assessing buccal bone width when the bone thickness is <0.5 mm⁴⁴. Although Lago et al.³⁶ reported that platform switching may preserve crestal bone levels and maintain soft tissue in esthetic zones, radiographic crestal bone levels are only an indirect measurement of esthetics outcome and thus platform switching does not necessarily directly improve esthetics.

Follow-up periods: Maintenance through follow-up visits is essential. However, a wide range of follow-up visits are reported. Straumann TL implants exhibited minimal changes in MBL during the follow-up periods, among which the maximum follow-up duration was 10 years²⁵.

V. Conclusion

There are several inconsistencies among studies and methodologies that limit precise comparisons. Bone alterations have been reported in different ways involving mean bone resorption, MBL, percentage of BL change, and the amount of BL change. Therefore, it makes exact comparisons impossible. Multifactorial characteristics of peri-implant bone resorption and diversity among implants and patients leads to a heterogeneity of results and cannot be applied to clinical indications. Clinicians must notice patient demands and

attempt to choose the most proper implant design based on clinical demands. Researchers should use patients who share common situations such as receiving similar prostheses, requiring augmentation, receiving same implant types, and the rehabilitation of similar edentulous areas to reduce systematic errors and potential bias. Biomaterial-related tissue reactions remain unclarified. The short-term nature of the results, limited sample size, and radiographic measurements of mesial and distal crestal BL changes are several limitations. Therefore, comparative long-term randomized clinical trials and a large number of patients are required.

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Authors' Contributions

H.M. participated in study design and performed analysis. A.K. (Amin Khodadoustan) participated in data collection. A.K. (Aida Kheiri) participated in data collection and wrote the manuscript. L.K. wrote the manuscript. All authors read and approved the final manuscript.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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