

RESEARCH

Open Access



Crestal bone loss around tissue level implants with platform matching abutments versus bone level implants with conical/platform switched abutments in the posterior mandible: a comparative study

Mahmoud Shalash^{1*}  and Ahmad Abdalsamad²

Abstract

Background: Many factors play a role in the long-term survival of osseointegrated dental implants. Among these, the preservation of crestal bone remains to be the key principal. The aim of this comparative study was to assess crestal bone loss (CBL) between tissue-level implants restored with platform matching abutments and bone-level implants restored with conical/platform switched hybrid abutments in the posterior molar region.

Results: All implants in both groups showed a 100% survival and success rate at 1 year. Mean CBL for group I was 0.8 mm (SD 0.85), and mean CBL for group II was 0.18 mm (SD 0.48). There was a statistically significant difference between the CBL in both groups ($p < 0.001$). The highest mean value was found in the tissue level group, while the lowest mean value was found in the bone level group.

Conclusion: Within the limitations of the sample size of this study, both implant designs showed minimal CBL at 1-year post-loading. Bone level implants with a platform switched conical hybrid connection showed less CBL compared to tissue level implants.

Keywords: Crestal bone loss, Tissue level implants, Conical connection, Platform switching, Morse taper, Bone level implants

Background

Crestal bone loss (CBL) around the neck of dental implants remains to be one of the most common problems following implant placement and influences the future success of the implant. Preservation of crestal bone results in stable soft tissues which in turn is critical for implant long-term survival.

Several factors have been attributed to CBL, including surgical trauma during implant bed preparation and

implant insertion, reduced thickness of buccal bone, reduced thickness of soft tissue at the implant site, stresses from occlusal loads at the implant neck, localized inflammatory reaction as a result of microleakage at the implant abutment junction (IAJ) and reestablishment of the biological width (Feng et al. 2018; Macedo et al. 2016; Oh et al. 2002; Linkevicius et al. 2015).

Of these factors, the presence of microleakage at IAJ seems pivotal in CBL at the implant neck. Two-piece implant systems are widely used by clinicians for replacing missing teeth. Due to precision limit during production, implants and their corresponding abutments cannot be accurately matched, resulting in a microscopic space between both parts or the so-called microgap. The

*Correspondence: dr_shalash@yahoo.com

¹ Surgery and Oral Medicine Department, National Research Centre, Cairo, Egypt

Full list of author information is available at the end of the article

passage of bacteria and its by-products freely through the microgap (microleakage) results in a constant state of inflammation at the IAJ, and this has been linked to CBL seen commonly around the implant neck (Liu and Wang 2017).

To overcome the effect of microleakage, several implant designs have been suggested. Of these, platform switching with or without using a Morse taper/conical connection, using regular and reduced implant diameters and changing the implant-abutment junction position to the alveolar bone crest as with tissue level implants have been proposed (Atieh et al. 2010; Petrie and Williams 2005).

By moving the IAJ vertically away in a supracrestal position as in the case of tissue level implants or horizontally in the case of platform switched implants, the effect of bacterial microleakage can be minimized (Lago et al. 2018). Moreover, Morse taper and conical interfaces which are normally platform switched can help eliminate bacterial microleakage by their cold-welding effect at the implant neck, restricting the in and out pumping of bacteria at the IAJ (D'Ercole et al. 2015; Mishra et al. 2017; Moergel et al. 2016).

With radiographic assessment being the most common modality to evaluate implant success, the concept of platform switching became established when long-term radiographic assessment of wide diameter implants that were restored with standard diameter abutments showed minimal CBL when compared to implants restored with prosthetic components having the same diameter (Lazara and Porter 2006; Luongo et al. 2008; Vigolo and Givani 2009; Joda et al. 2015).

Similar observations were found, where many studies have shown that CBL is minimized when two-piece tissue level implants are used. Tissue level implants have an added advantage of being placed in a one-stage surgery, reducing the overall treatment time with a shorter healing period (Kim et al. 2008, 2018; Derks and Tomasi 2015).

Recent modifications in implant and abutment designs have introduced hybrid connections, meaning that both a Morse taper design and a regular hexagonal/polygonal shape of anti-rotational or guiding grooves are present (Liu and Wang 2017).

With so many connection designs available as well as different implant placement protocols and to the best of our knowledge, there are very few randomized control trials comparing the CBL between tissue level implants with platform matching interface and bone level platform switched implants with a conical/hybrid interface. This study aims to compare the radiographic bone level changes between both designs after 1 year of loading.

Methods

This study was carried out in the outpatient clinic of the National Research Centre, Cairo, Egypt, from August 2018 till November 2019 with inclusion criteria of patients missing single or multiple teeth in the posterior mandible requiring implant therapy. Ethical approval was obtained from the ethics and research committee at the National Research Centre, Cairo, Egypt. (ethical approval number 20057). The study was also performed in accordance with the Helsinki Declaration. Individuals with any known systemic condition that would interfere with bone metabolism, poor oral hygiene, gingival or periodontal disease and smokers were excluded from this study.

Inclusion criteria

Individuals aged 22 years and above missing single or multiple teeth in the posterior mandible for at least 6 months require rehabilitation with a fixed implant supported restorations. All patients were nonsmokers. Implant sites should exhibit adequate width and height to allow placement of implants without the need for any bone regeneration procedures. All patients were consented and informed about the nature of the procedure and the required follow-up period.

Sample size calculation

With a null hypothesis of 0.4 mm difference (Lago et al. 2018) in CBL between both groups to achieve a power of 95% and with significance level 0.05 using a two-sided *t* test; group sample size of 28 implants in each group was calculated. To compensate for possible drop-outs or implant failure, the numbers were adjusted to 30 implants per group.

Patient grouping and randomization

Patients were randomly divided into two groups, group one: tissue level implants, (Zimmer swiss plus, Zimmer Biomet, USA) included 20 patients (12 females and 8 males) who received 30 implants; and group two: bone level implants, (Roott, Trate AG, Switzerland) included 14 patients (9 males and 5 females) who received 30 implants. Randomization was carried out by a statistician using predefined randomization tables. A balanced random permuted block approach was used to prepare the randomization tables to avoid unequal balance between the two groups taking into account the variables of age, sex and bone density. Allocation was done by an examiner not involved in the initial patient assessment or to the surgical procedure, who received a concealed envelope for each patient for assignment to either one of the two study groups. The envelope would be opened at the time of surgery. Only the participants involved in the

study were blinded as whether they will be in the tissue level or bone level group.

A brief medical and dental history, followed by clinical examination, was carried out for all patients. A visual inspection of the area of interest was carried out, confirming that there were no local conditions interfering with implant placement. An initial digital periapical radiograph (Diogra Optime, Sordex, Sweden) was carried out to exclude the presence of any lesions, pathology or remaining roots in the area of interest. A CBCT scan (Cranex[®] 3DX, SOREDEX, Sweden) was then done as the final investigation to accurately assess the available bone volume in terms of height and width.

Surgical procedures

All the surgical and restorative procedures were performed by the same operator for both groups following established protocols. All patients received a prophylactic dose of Amoxicillin 2 gm (Augmentin, gsk, UK) or clindamycin 600 mg (Dalacin C, Pfizer, USA) in case of penicillin allergy and ibuprofen 400 mg (Brufen, Cairo pharmaceuticals, Egypt) 30 min before the surgery. The antibiotic was continued for 3 days after the procedure (Lago et al. 2018). Local anesthesia was induced using Articaine HCL 4% with 1;200,000 epinephrine (Articaine, Artinbsa, Spain). Full thickness mucoperiosteal flaps were raised using a crestal incision. Implant placement was done according to manufacturer instructions following sequential drilling using a series of twist drills. Implants in both groups were placed such that the

rough implant surface was at the level of the bone crest (Figs. 1a, 2a). Healing abutments were connected to the bone level implants to achieve a one-stage surgical protocol similar to tissue level implants (Figs. 1b, 2b). Periapical radiographs were taken for intraoperative control. Soft tissue was sutured using prolene 5–0 (Ethicon, Johnson and Johnson, USA). Oral hygiene instructions were given to all patients. Suture removal was done 1 week after the procedure. A total of 30 tissue level swiss plus implants (Zimmer swiss plus, Zimmer Biomet, USA) were placed with diameters 3.7, 4.1 and 4.8 mm and length ranging from 8 to 12 mm. A total of 30 bone level roott implants (Roott, Trate AG, Switzerland) with diameters 3.8, 4.2 and 4.8 mm and length 8–12 mm were placed. All implants were left to heal for a minimum of 2 months before prosthetic loading.

After successful osseointegration, all implants were restored with appropriate abutments and loaded with cement retained porcelain fused to metal crowns (Figs. 1c, d, 2c, d).

Radiographic assessment

To assess crestal bone level changes following implant loading, two digital periapical radiographs were done for each patient using the paralleling technique. The first radiograph was taken immediately after each implant was restored; the second image was done after 12 months.

The radiographs were imaged with (Progeny, Midmark, USA) x-ray machine using DIGORA[™] Optime UV (Soredex, Finland). A “size 2” Digora imaging plate was used

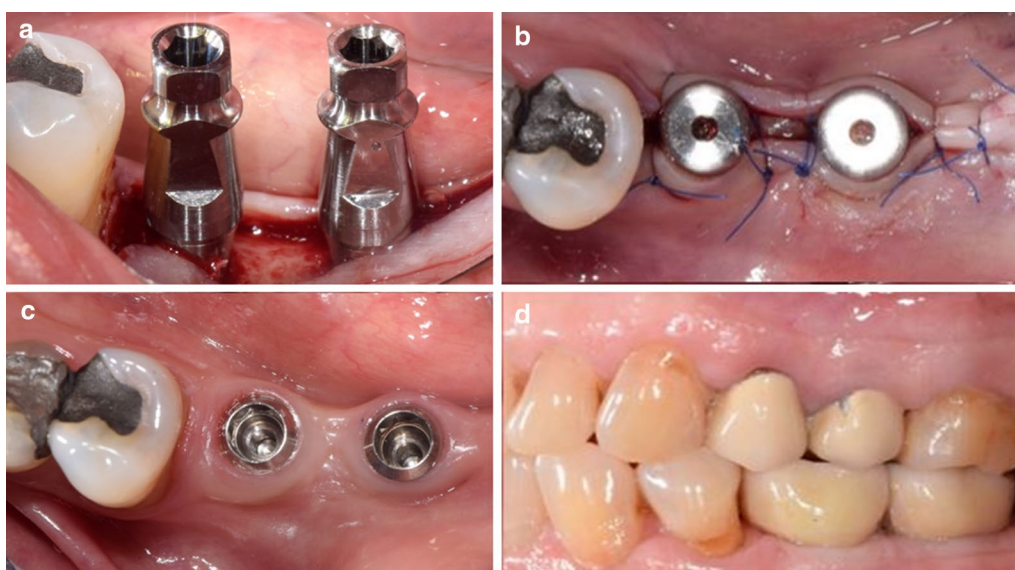


Fig. 1 Tissue level implants. **a** Insertion the with polished rough surface at the level of the bone crest, **b** healing abutments placed at tissue level, **c** and **d** healing and final restoration

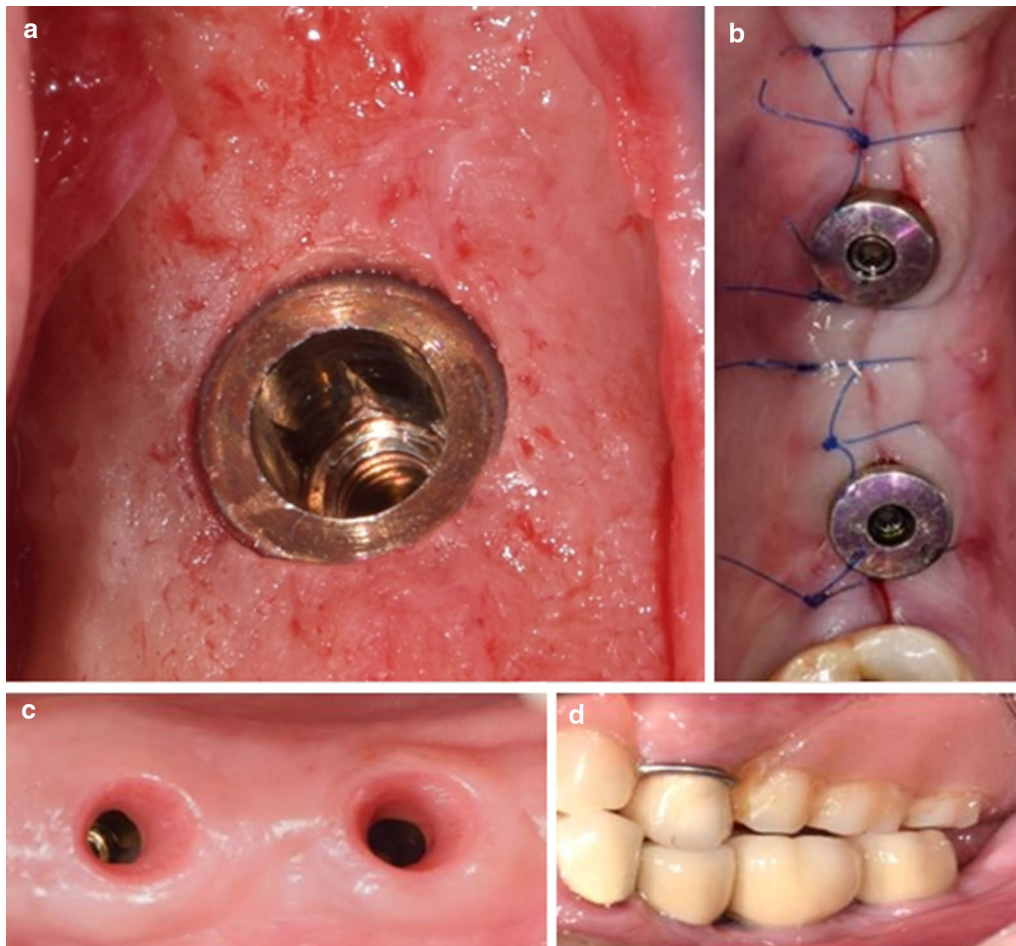


Fig. 2 Bone level implants. **a** Insertion up to the level of the bone crest, **b** healing abutments placed for a one-stage surgery, **c** and **d** healing and final restoration

with a film holder and a radiographic stent for standardization of film holder angulation and position during follow-up.

Assessment was done using Digora for windows 2.5 software (Soredex, Finland). Calibration of each radiograph was done by using the implant diameter as a reference (Lago et al. 2018; Moergel et al. 2016). For the bone level group, the platform of the implant was used as a reference for measurements. A line was drawn perpendicular from implant platform to the most coronal implant-to-bone contact. The distance between the platform and the first implant-to-bone contact was measured mesially and distally to the nearest 0.1 mm.

For the tissue level group, since the implant platform cannot be accurately detected on the radiograph, we decided to choose the abutment screw channel as our reference area. This area appears halo on the x-ray. The reference line was demarcated by the first thread of the abutment screw which corresponded to the transition

zone between the smooth and rough surfaces of the implant. A reference line was then drawn at this transition zone, and measurements were taken off that line in a similar manner to the bone level group (Fig. 3a, b). For both groups, the average of both the mesial and distal measurement for each implant was made. The difference between the readings of both the initial and 12 months radiographs was calculated to determine the CBL. For patients that received more than one implant, the mean CBL of each implant was calculated. The same steps were repeated with each radiograph (Guerra et al. 2014; Pellicer-Chover et al. 2016). All measurements were taken by an oral and maxillofacial radiologist with an experience of 14 years; twice in 2 separate sessions 2 weeks apart from each other. For those measurements that were inconsistent at the second reading, a second examiner was consulted to reach an agreement on the correct measurement.

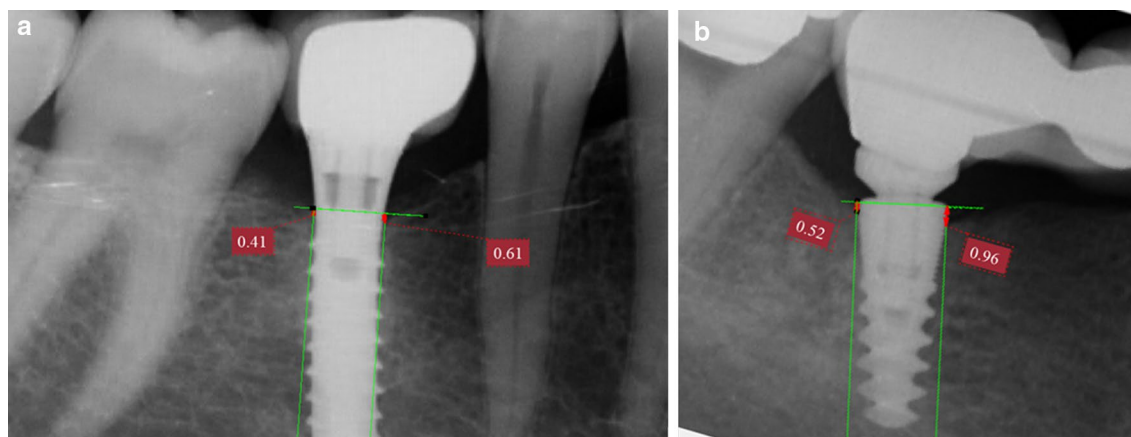


Fig. 3 Showing mesial and distal measurements of the first bone-to-implant contact, **a** tissue level implants and **b** bone level implants

Statistical analysis

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov–Smirnov and Shapiro–Wilk tests. Data showed nonparametric (not-normal) distribution. The Mann–Whitney test was used to compare between the two groups in nonrelated samples. The Wilcoxon test was used to compare between the two groups in related samples. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Results

Among all patients examined from August 2018 till November 2019, a total of 60 implants were placed in 34 patients that were divided randomly into two groups. Group I (tissue level) included 20 patients (12 females and 8 males) with a mean age of 38.8 years, who received 30 implants. Before implants loading, one patient (2 implants) were excluded from the study due to patient drop out. Group II (bone levels) included 14 patients (10 males and 4 females) with a mean age range of 37.2 years, received a total of 30 implants. All patients were non-smokers and did not have any medical contraindication for dental implants placement (Fig. 4).

Clinical results

All implants healed uneventfully. One patient dropped out from group I during the follow-up period. All other implants showed a survival and success rate of 100%. Clinically, there were no signs of inflammation or bleeding upon probing. Patient reported full satisfaction with their implant restorations.

Radiographic results

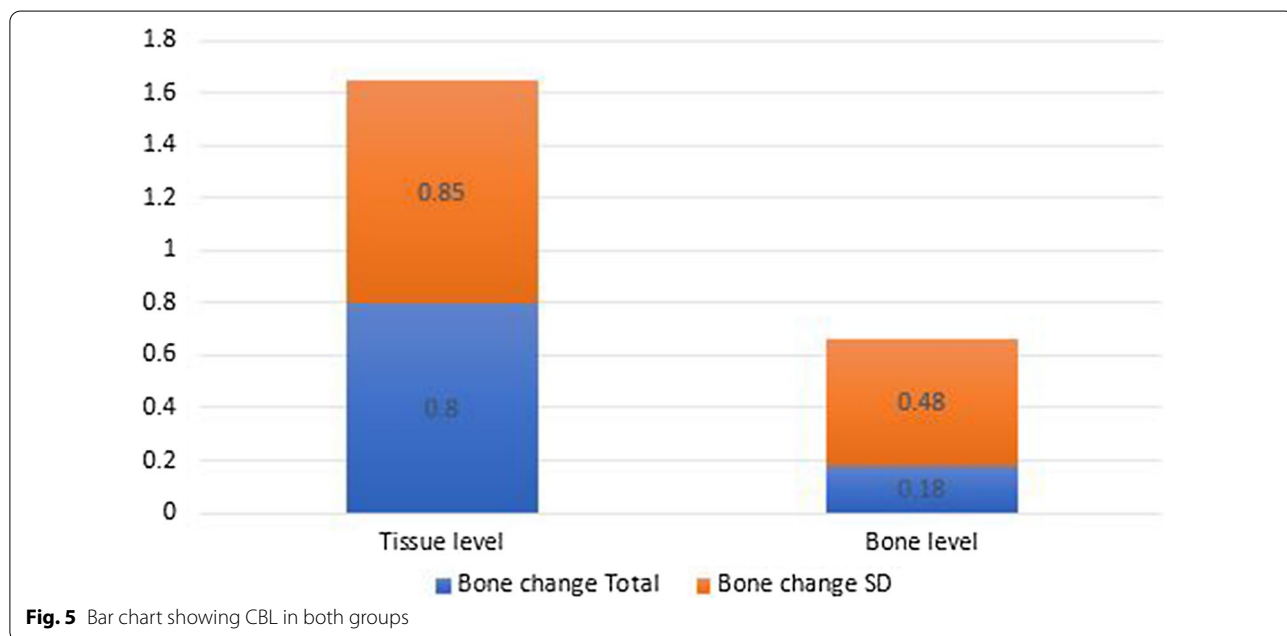
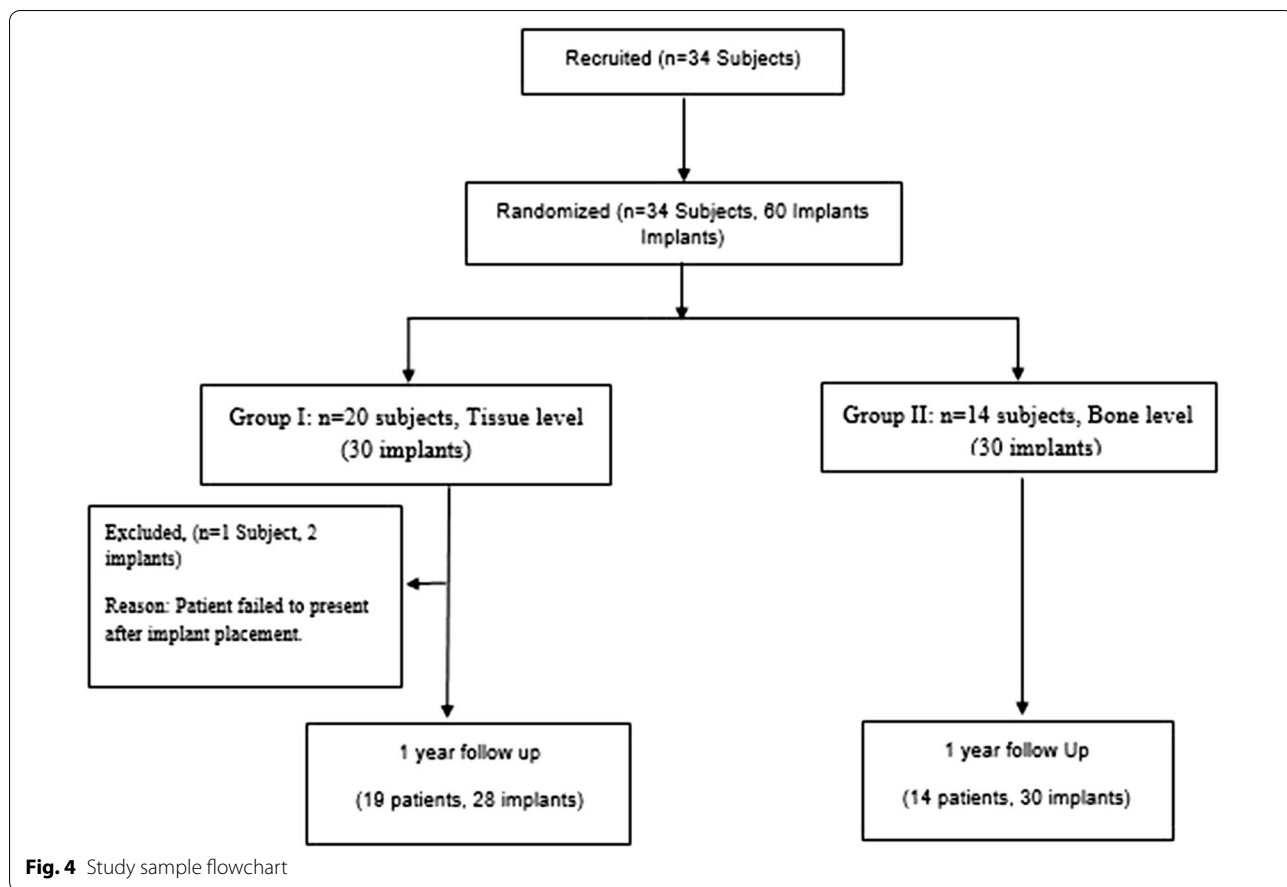
The mean CBL following loading of the implants in both groups was assessed. A mean CBL of 0.8 mm (SD 0.85) was found in the tissue level group compared to a mean CBL of 0.18 mm (SD 0.48) in the bone level group. There was a statistically significant difference between the means of CBL in both groups ($p < 0.001$). The highest mean value was found in the (Tissue level) group, while the lowest mean value was found in (Bone level) group (Fig. 5).

Discussion

The assessment of crestal bone loss around dental implants has been a subject of extensive research since this has been a major factor in predicting the prognosis and long-term survival of dental implants.

Very early studies have shown that an expected CBL of 1.5 mm during the first year of function followed by less than 0.2 mm in the following years is expected and was considered a determinant for successful implant treatment (Brånemark et al. 1977; Adell et al. 1981; Laney et al. 1997). Recent studies that followed have shown that after 3 years in function, the cumulative interproximal, clinical and radiographic bone loss was calculated to be below 0.5 mm irrespective of the implant surface or design (Abrahamsson and Berglundh 2009; Lang and Jepsen 2009).

In our study, group I included patients that received tissue level implants that were placed such that the junction between the smooth and rough surface was at the crest of the bone. Early studies assessing CBL around tissue level implants showed that the crest of the bone remodeled to 1 mm below the rough/smooth implant border at 1–2 years after loading (Buser et al. 1988, 1990). In a



1-year radiographic study, Brägger et al. (1998) showed an initial bone loss during healing and early functional loading of tissue level implants to be around 0.8 mm.

In a comparative study, Hänggi et al. (2005) compared two different designs of tissue level implants, one with a 2.8 mm and the other with 1.8 mm smooth collar. In a total of 201 implants placed, a mean CBL of 0.5 mm and 0.7 mm, respectively, was found in each group after 1 year of loading with most of the loss happening in the early phase of healing before the abutments were connected. Fernández-Formoso et al. (2012) showed a mean CBL of 0.4 mm at 1 year following loading of tissue level implants. Lago et al. (2018) evaluated 100 tissue level implants placed and followed up for 5-year post-loading showed a mean CBL of 0.61 mm (± 0.73) from baseline measurements.

A recent systematic review and meta-analysis assessing the effect of implant-abutment junction position on crestal bone loss using different implant designs and placement protocols showed that tissue level implants exhibited a mean CBL of 0.68 mm during the early healing period and a further 0.1 mm CBL following abutment connection with cumulative bone loss of 0.69 mm (± 0.54) (Saleh et al. 2018). Our results showed a mean CBL of 0.82 mm at 1-year post-loading which is the same as the study of Brägger et al. (1998) and is in same range as many of studies published in the literature assessing CBL around tissue level implants.

The use of platform switched conical abutment connection systems at the IAJ has been reviewed in the literature. It has been claimed that with this attachment system, the risk of bacterial microleakage can be minimized at the IAJ thus retarding or preventing bacterial colonization (Tesmer et al. 2009).

Kütan et al. (2015) showed in a randomized control trial that the mean CBL after 3 years loading of implants restored with a Morse taper connection to range from 0.5 to 1.21 mm depending on whether the implants are placed at the level of the bone crest, as in our study or 1 mm below the bone crest. Although more resorption occurred in the implants placed 1 mm below the crest, the bone loss did not reach the implant first thread compared to implants placed in the equicrestal position, supporting the hypothesis that placing implants with a Morse taper connection 1 mm below the bone crest helps to protect the marginal bone.

In a split mouth clinical trial, Al Amri et al. (2017) showed that the mean CBL after 3 years of loading of implants with Morse taper connection placed equicrestally or 2 mm subcrestally to be 0.45 ± 0.2 and 0.3 ± 0.2 mm, respectively. In our study, the mean CBL after 1 year of loading in group II was 0.18 mm which is in accordance with the most published literature Moergel

et al. (2016) (0.12 ± 0.42 mm), Kielbassa et al. (2009) (0.30 ± 0.16 mm), Canullo et al. (2010) (0.37 ± 0.12 mm) and Pieri et al. (2011) (0.20 ± 0.17 mm).

Several publications have shown that there is no difference in crestal bone level changes between platform switched and platform matching abutments (Crespi et al. 2009; Kielbassa et al. 2009; Enkling et al. 2011; Dursun et al. 2012). However, many systematic reviews reported significantly lower bone loss in implants restored with platform switching compared to platform matching (Annibali et al. 2012; Herekar et al. 2014; Strietzel et al. 2015; Chrcanovic et al. 2015; Santiago et al. 2016).

Our results seem to be in agreement with this, and it was obvious that implants in group two restored with platform switched conical hybrid abutments had less CBL than those in group I. According to Mangano et al. (2009), the incorporation of platform switching together with internal connection enhances the stress distribution at the IAJ and improves mechanical stability in addition to minimizing the microleakage.

We believe that the hybrid design employed in the bone level implant system used in this study offered more stability to the abutment under cyclic loading which further contributed to the minimized bone loss found in this group. This is in accordance with the results of Sammour et al. (2019) which showed that conical hybrid abutments showed better stability than internal hex connections under cyclic loading.

It is worth noting that only digital periapical radiography was used as the modality for assessing CBL in this study based on the recommendations of the American academy of oral and maxillofacial radiology considering this to be the modality of choice for postoperative assessment in the absence of clinical signs and symptoms. CBCT is not suitable for assessing marginal changes around dental implants owing to the streak artifacts around titanium fixtures which can mask any minute bone changes (2012).

One of the limitations of this study was the short 1-year follow-up period. A longer follow-up would have further helped identify the bone response to different designs and placement protocols. Also, a third group with bone level implants and platform matching abutments would have further helped to validate the findings of this study.

Conclusion

Both tissue level implants with platform matching abutments and bone level implants with platform switched conical hybrid abutments seem to preserve crestal bone levels around the implant neck. Both designs exhibited CBL after 1 year of loading. The mean CBL between both groups was found to be statistically significant. Bone level implants with a platform switched conical

hybrid connection showed less CBL compared to tissue level implants. This, however, did not seem to have any clinical implications. More studies with a longer follow-up period and a larger sample size are needed to further evaluate the bone response to different connection designs and placement protocols.

Abbreviations

CBL: Crestal bone loss; IAJ: Implant abutment junction.

Acknowledgements

Authors would like to acknowledge Dr. Mohamed Mounir, Lecturer of Oral Surgery, Faculty of dentistry, Cairo University for the assistance in the randomization process and patient grouping and Dr. Yara Rabie Helely, Lecturer of Oral and maxillofacial radiology, Faculty of dentistry, Cairo University, for the assistance in the radiographic measurements.

Author's contributions

MS was the operator in all the cases, both surgical and prosthetic procedures and he also wrote the manuscript. AS worked on data analysis and measurements for the radiographs and also assisted in drafting the manuscript. All authors have read and approved the manuscript.

Funding

Self-funded.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Approved by the ethical committee of the National Research Centre. All patients signed a consent to participate in the study. Ethical approval number 20057

Consent for publication

Institutional consent form was used and presented to the ethical committee before approval.

Competing interests

The authors declare that they have no competing interests.

Author details

¹ Surgery and Oral Medicine Department, National Research Centre, Cairo, Egypt. ² Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University, Cairo, Egypt.

Received: 1 October 2020 Accepted: 22 October 2020

Published online: 31 October 2020

References

- Abrahamsson I, Berglund T (2009) Effects of different implant surfaces and designs on marginal bone-level alterations: a review. *Clin Oral Implants Res* 20:207–215
- Adell R, Lekholm U, Rockler B, Brånemark P-I (1981) A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg* 10:387–416
- Al Amri MD, Al-Johany SS, Al Baker AM, Al Rifaiy MQ, Abduljabbar TS, Al-Kheraif AA (2017) 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* 28:1342–1347
- Annibaldi S, Bignozzi I, Cristalli MP, Graziani F, La Monaca G, Polimeni A (2012) Peri-implant marginal bone level: a systematic review and meta-analysis of studies comparing platform switching versus conventionally restored implants. *J Clin Periodontol* 39:1097–1113
- Atieh MA, Ibrahim HM, Atieh AH (2010) Platform switching for marginal bone preservation around dental implants: a systematic review and meta-analysis. *J Periodontol* 81:1350–1366
- Brägger U, Häfeli U, Huber B, Hämmerle CHF, Lang NP (1998) Evaluation of postsurgical crestal bone levels adjacent to non-submerged dental implants. *Clin Oral Implants Res* 9:218–224
- Brånemark PI, Hansson BO, Adell R et al (1977) Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand J Plast Reconstr Surg Suppl* 16:1–132
- Buser DA, Schroeder A, Sutter F, Lang NP (1988) The new concept of ITI hollow-cylinder and hollow-screw implants: Part 2. Clinical aspects, indications, and early clinical results. *Int J Oral Maxillofac Implants* 3:173–181
- Buser D, Weber HP, Brägger U (1990) The treatment of partially edentulous patients with ITI hollow-screw implants: presurgical evaluation and surgical procedures. *Int J Oral Maxillofac Implants* 5:165–175
- Canullo L, Fedele GR, Iannello G, Jepsen S (2010) Platform switching and marginal bone-level alterations: the results of a randomized-controlled trial. *Clin Oral Implants Res* 21:115–121
- Chrcanovic BR, Albrektsson T, Wennerberg A (2015) Platform switch and dental implants: a meta-analysis. *J Dent* 43:629–646
- Crespi R, Cappare P, Gherlone E (2009) Radiographic evaluation of marginal bone levels around platform-switched and non-platform-switched implants used in an immediate loading protocol. *Int J Oral Maxillofac Implants* 24:920–926
- D'Ercole S, Tripodi D, Marzo G et al (2015) Microleakage of bacteria in different implant-abutment assemblies: an in vitro study. *J Appl Biomater Funct Mater* 13:e174–e180
- Derks J, Tomasi C (2015) Peri-implant health and disease: a systematic review of current epidemiology. *J Clin Periodontol* 42:S158–S171
- Dursun E, Tulunoglu I, Canpinar P, Uysal S, Akalin FA, Tözüm TF (2012) Are marginal bone levels and implant stability/mobility affected by single-stage platform switched dental implants? A comparative clinical study. *Clin Oral Implants Res* 23:1161–1167
- Enkling N, Jöhren P, Klimberg V, Bayer S, Mericske-Stern R, Jepsen S (2011) Effect of platform switching on peri-implant bone levels: a randomized clinical trial. *Clin Oral Implants Res* 22:1185–1192
- Feng Y, He F, Luo X, Li J (2018) Effect of initial biologic width on crestal bone loss— a clinical retrospective study of 1–5 years. *Clin Oral Implants Res* 29:321–321
- Fernández-Formoso N, Rilo B, Mora MJ, Martínez-Silva I, Díaz-Afonso AM (2012) Radiographic evaluation of marginal bone maintenance around tissue level implant and bone level implant: a randomised controlled trial. A 1-year follow-up. *J Oral Rehabil* 39:830–837
- Guerra F, Wagner W, Wiltfang J et al (2014) Platform switch versus platform match in the posterior mandible—1-year results of a multicentre randomized clinical trial. *J Clin Periodontol* 41:521–529
- Hänggi MP, Hänggi DC, Schoolfield JD, Meyer J, Cochran DL, Hermann JS (2005) Crestal bone changes around titanium implants. Part I: a retrospective radiographic evaluation in humans comparing two non-submerged implant designs with different machined collar lengths. *J Periodontol* 76:791–802
- Herekar M, Sethi M, Mulani S, Fernandes A, Kulkarni H (2014) Influence of platform switching on periimplant bone loss: a systematic review and meta-analysis. *Implant Dent* 23:439–450
- Joda T, Michelaki I, Heydecke G (2015) Peri-implant bone loss of dental implants with platform-switching design after 5 years of loading: a cross-sectional study. *Quintessence Int* 46:59–66
- Kielbassa AM, de Fuentes RM, Goldstein M et al (2009) Randomized controlled trial comparing a variable-thread novel tapered and a standard tapered implant: interim one-year results. *J Prosthet Dent* 101:293–305
- Kim DM, Badovinac RL, Lorenz RL, Fiorellini JP, Weber HP (2008) A 10-year prospective clinical and radiographic study of one-stage dental implants. *Clin Oral Implants Res* 19:254–258
- Kim S, Jung UW, Cho KS, Lee JS (2018) Retrospective radiographic observational study of 1692 Straumann tissue-level dental implants over 10 years: I. Implant survival and loss pattern. *Clin Implant Dent Relat Res* 20:860–866
- Kütan E, Bolukbasi N, Yildirim-Ondur E, Ozdemir T (2015) Clinical and radiographic evaluation of marginal bone changes around platform-switching

- implants placed in crestal or subcrestal positions: a randomized controlled clinical trial. *Clin Implant Dent Relat Res* 17:e364–e375
- Lago L, da Silva L, Martinez-Silva I, Rilo B (2018) Crestal bone level around tissue-level implants restored with platform matching and bone-level implants restored with platform switching: a 5-year randomized controlled trial. *Int J Oral Maxillofac Implants* 33:448–456
- Laney WR, Jemt T, Harris D et al (1997) Osseointegrated implants for single-tooth replacement: progress report from a multicenter prospective study after 3 years. *Int J Oral Maxillofac Implants* 9:49–54
- Lang NP, Jepsen S (2009) Implant surfaces and design (Working Group 4). *Clin Oral Implants Res* 20:228–231
- Lazzara RJ, Porter SS (2006) Platform switching: a new concept in implant dentistry for controlling postrestorative crestal bone levels. *Int J Periodontics Restorative Dent* 26:9–17
- Linkevicius T, Puisys A, Steigmann M, Vindasiute E, Linkeviciene L (2015) Influence of vertical soft tissue thickness on crestal bone changes around implants with platform switching: a comparative clinical study. *Clin Implant Dent Relat Res* 17:1228–1236
- Liu Y, Wang J (2017) Influences of microgap and micromotion of implant-abutment interface on marginal bone loss around implant neck. *Arch Oral Biol* 83:153–160
- Luongo R, Traini T, Guidone PC, Bianco G, Cocchetto R, Celletti R (2008) Hard and soft tissue responses to the platform-switching technique. *Int J Periodontics Restorative Dent* 28:551–557
- Macedo JP, Pereira J, Vahey BR et al (2016) Morse taper dental implants and platform switching: the new paradigm in oral implantology. *Eur J Dent* 10:148–154
- Mangano C, Mangano F, Piattelli A, Iezzi G, Mangano A, La Colla L (2009) Prospective clinical evaluation of 1920 Morse taper connection implants: results after 4 years of functional loading. *Clin Oral Implants Res* 20:254–261
- Mishra SK, Chowdhary R, Kumari S (2017) Microleakage at the different implant abutment interface: a systematic review. *J Clin Diagn Res* 11:10–15
- Moergel M, Rocha S, Messias A, Nicolau P, Guerra F, Wagner W (2016) Radiographic evaluation of conical tapered platform-switched implants in the posterior mandible: 1-year results of a two-center prospective study. *Clin Oral Implants Res* 27:686–693
- Oh T-J, Yoon J, Misch CE, Wang H-L (2002) The causes of early implant bone loss: myth or science? *J Periodontol* 73:322–333
- Pellicer-Chover H, Peñarrocha-Diago M, Peñarrocha-Oltra D, Gomar-Vercher S, Agustín-Panadero R, Peñarrocha-Diago M (2016) Impact of crestal and subcrestal implant placement in peri-implant bone: a prospective comparative study. *Med Oral Patol Oral Cir Bucal* 21:e103–e110
- Petrie CS, Williams JL (2005) Comparative evaluation of implant designs: influence of diameter, length, and taper on strains in the alveolar crest—a three-dimensional finite-element analysis. *Clin Oral Implants Res* 16:486–494
- Pieri F, Aldini NN, Marchetti C, Corinaldesi G (2011) Influence of implant-abutment interface design on bone and soft tissue levels around immediately placed and restored single-tooth implants: a randomized controlled clinical trial. *Int J Oral Maxillofac Implants* 26:169–178
- Saleh MHA, Ravidà A, Suárez-López del Amo F, Lin GH, Asa'ad F, Wang HL (2018) The effect of implant-abutment junction position on crestal bone loss: a systematic review and meta-analysis. *Clin Implant Dent Relat Res* 20:617–633
- Sammour SR, Maamoun El-Sheikh M, Aly E-G (2019) Effect of implant abutment connection designs, and implant diameters on screw loosening before and after cyclic loading: in-vitro study. *Dent Mater* 35:e265–e271
- Santiago JF, De Souza Batista VE, Verri FR et al (2016) Platform-switching implants and bone preservation: a systematic review and meta-analysis. *Int J Oral Maxillofac Surg* 45:332–345
- Strietzel FP, Neumann K, Hertel M (2015) Impact of platform switching on marginal peri-implant bone-level changes. A systematic review and meta-analysis. *Clin Oral Implants Res* 26:342–358
- Tesmer M, Wallet S, Koutouzis T, Lundgren T (2009) Bacterial colonization of the dental implant fixture-abutment interface: an in vitro study. *J Periodontol* 80:1991–1997
- Tyndall DA, Price JB, Tetradis S, Ganz SD, Hildebolt C, Scarfe WC (2012) Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol* 113:817–826
- Vigolo P, Givani A (2009) Platform-switched restorations on wide-diameter implants: a 5-year clinical prospective study. *Int J Oral Maxillofac Implants* 24:103–109

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Submit your manuscript to a SpringerOpen® journal and benefit from:

- Convenient online submission
- Rigorous peer review
- Open access: articles freely available online
- High visibility within the field
- Retaining the copyright to your article

Submit your next manuscript at ► [springeropen.com](https://www.springeropen.com)