The Effect of Initial Biologic Width on Marginal Bone Loss: A Retrospective Study

Ping Sun, DDS, MD1/Dan Yu, DDS, MDS1/Xin Luo, DDS, MDS, MDS2/Antian Xu, DDS, PhD1/Yi Feng, DDS, MDS1/Fu-ming He, DDS, MD1

Purpose: To evaluate the short-term effect of dental implant placement, mucosa thickness, and their combined effects (initial biologic width) on marginal bone loss. Materials and Methods: This was a retrospective study on patients who received implant surgery in the posterior region without bone augmentation surgery between 2012 and 2016, and implants had been loaded for more than 12 months. Each patient received radiographic examination before and after implant surgery, before the stage-two surgery, and during the 1- to 5-year follow-up. The thickness of mucosa, depth of dental implant placement, and crestal bone loss were evaluated on digital radiographs. The interaction was discussed by defining the combination of initial mucosal thickness and implantation depth as the initial biologic width. The implants were divided into four study groups based on the quartile of the initial biologic width. Results: This study included 266 patients (94 male and 172 female, 22 to 85 years of age, mean age: 51.43 years), with 413 dental implants placed including 239 Straumann implants and 174 Ankylos implants. The average follow-up was 21.50 months. After 1 to 5 years, the median crestal bone loss around implants was 0.35 mm (0.30 mm for Straumann BL and 0.40 mm for Ankylos). The implants were divided into four groups: group A (≤ 2.85 mm), group B (2.85 to 3.40 mm), group C (3.40 to 3.97 mm), and group D (> 3.97 mm). Group B showed significantly less crestal bone loss than group A (0.38 mm vs 0.25 mm; \( P < .05 \)) and group C (0.25 mm vs 0.40 mm; \( P < .05 \)) during the follow-up. Significantly more crestal bone loss around implants was observed in the thin mucosa group than in the thick mucosa group (0.50 mm vs 0.30 mm; \( P < .001 \)), while implants placed even with the bone level displayed a significantly higher amount of marginal bone loss than implants placed even with the bone crest (0.50 mm vs 0.10 mm; \( P < .001 \)). Conclusion: The initial biologic width has an effect on crestal bone loss. When the initial biologic width was between 2.85 and 3.40 mm, the marginal bone loss was lowest. Based on radiographic evaluation, implants placed in thick gingiva and even with the bone level showed less alveolar marginal bone loss compared with implants placed in thin gingiva and below the crestal bone level. Int J Oral Maxillofac Implants 2022;37:190–198. doi: 10.11607/jomi.9169

Keywords: biologic width, marginal bone loss, mucosal thickness, placement level

The term “biologic width” builds on the work by Gar- giulo et al on the average dimension of the epithelial junction (0.97 mm) and connective tissue attachment (1.07 mm) and the relationship of their components. The space of the biologic width was necessary to maintain healthy soft and hard tissues in prosthetic and restorative rehabilitations. To date, many studies have investigated biologic width around the implant to inhibit bacterial invasion and food residues entering the implant-tissue interface. According to histometric analysis, mean values around submerged-approach titanium implants were 0.13 to 0.14 mm for sulcus depth, 1.50 to 2.31 mm for junctional epithelium, 1.35 to 1.70 mm for connective tissue contact, and 3.33 to 3.80 mm for biologic width. Fibers are arranged circularly and horizontally around the abutment. The junctional epithelium was tightly attached to the implant surface via a hemidesmosome-like structure. It seems that soft tissue firmly sealed around the neck of the implant and protected the bone. The biologic width forms when the implants are uncovered for healing. This process leads to bone exposure to the oral cavity; thus, the bacteria reaches the interface between the implant and the abutment. An animal study depicted the
details on biologic width formation around the implant, including the loss of marginal bone.12 The occurrence of epithelial barrier was first observed in the marginal soft tissue.12 At the same phase, bone remodeling was intense.12 The establishment of biologic width may partially explain early crestal bone loss (CBL).4 The space of biologic width and the amount of bone loss probably was associated with the vertical position of implants and the thickness of soft tissue at the surgical site.4

Studies have focused on the influence of the vertical position of implants on marginal bone resorption, but the conclusions are inconsistent. Some clinical studies and animal experiments reported that when dental implants were placed underneath the bone, they showed more bone loss.13–15 However, in other studies, implants placed at the subcrestal or crestal level had no effect on bone resorption.16–19 Conversely, subcrestal implants showed better preservation of the bone.20 Most recommendations suggested that implants should be placed below the bone level.21,22 Considering the possible bone resorption, the subcrestal position would help protect the mucosa,23 avoid implant surface exposure, and further prevent mucositis or peri-implantitis.20,22,24

Previous studies suggested that a certain preexisting minimal thickness of peri-implant mucosa is a prerequisite for stable soft tissue attachment.25–27 A recent systematic review and meta-analysis confirmed that when the implants were placed with thicker initial soft tissue around implants, there was less radiographic CBL, and it was determined that the soft tissue thickness required to establish the biologic width was at least 2 mm.28 If the soft tissue dimension failed to meet the requirement, bone resorption would occur to ensure the adequate epithelial-connective tissue attachment.20,25 In addition, the design of the implant, the time when the load starts, the design of the prosthesis, and even patient-related factors would all have an impact on the peri-implant bone resorption.4,29–32

To avoid the exposure of a rough implant neck, the depth of the implant placement should be adjusted to the thickness of the mucosa during implant surgery.33 Therefore, the vertical position of implants and gingival thickness need to be combined, ie, the initial biologic width, to analyze the impact on the crestal bone loss. This study aimed to explore whether there is an initial biologic width value that minimizes bone resorption in the implant neck, and whether this value is consistent with the reported biologic width value. It is hypothesized that when the initial biologic width is set to approximately 3 to 4 mm, peri-implant bone resorption would be minimal. Namely, the thinner the mucosa soft tissue is, the deeper the implants should be placed in the alveolar bone. In this study, the effects of the depth of the implant, the mucosa thickness, and the initial biologic width on the marginal bone loss were evaluated.

MATERIALS AND METHODS

Study Design and Patient Selection

This was a retrospective study and was approved by the Ethics Committee of Stomatology Hospital, School of Medicine, Zhejiang University, China (No.2018001). Patients included in this study had implants placed in the posterior region in The affiliated stomatology hospital, medicine college, Zhejiang University from 2012 to 2016 with written informed consent. Inclusion criteria were as follows: (1) good general health and (2) adequate bone height and width. Exclusion criteria were as follows: (1) systemic contraindications (uncontrolled endocrine disorders, metabolic bone disorders, history of radiotherapy or chemotherapy); (2) poor oral hygiene; (3) active periodontal infections; (4) bruxism; and (5) heavy smoking habit (> 10 cigarettes/day). In addition, all patients were given a periodic recall check.

Appropriate preoperative treatments for dental caries and periodontal diseases were conducted. An oral panoramic radiograph (OPG; orthopantomograph OP 200 D, Instrumentarium) was used to calculate the bone crest height. Two different implant systems were used: Straumann (Straumann BL, Institut Straumann) and Ankylos (Ankylos, Friadent). Implants were placed according to the Straumann or Ankylos system manual under local anesthesia. OPG was performed after the implantation operation to assess the position of the implant. After 3 months, the patients returned for restoration. OPG was performed to rule out pathologic bone transparency around the implant. Implant-supported restorations including single crowns or prostheses were delivered to the patients. Patients were called back for follow-up evaluation after at least 12 months of implant loading. The clinical assessment was conducted for implants, prostheses, and peri-implant tissues. The mean probing depth (PD) was calculated using a Williams probe on six sites of the implant (mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual, and distolingual).34 Peri-implant infection around the implants was evaluated based on whether bleeding on probing (BOP) appeared during the first 30 seconds (0 = absent, 1 = present).35,36 Plaque Index (PLI) was assigned based on the amount of plaque (0 = no plaque detected, 1 = plaque only recognized by running a probe, 2 = plaque seen by naked eye, 3 = abundance of soft matter).37

A radiographic assessment was performed on digital OPG by using Clinview Software version 6.1.3.7 (Instrumentarium Imaging) by two independent examiners (D.Y., X.L.).38 OPG was performed before and after the implantation operation, before the stage-two surgery, and loaded after more than 12 months of follow-up. Figure 1 shows the method of the crestal bone level measurements and reference lines.38 The implant length was used as the reference for measurement; also, the distance between the
implant platform and the most coronal aspect of the bone was measured mesially and distally for each implant. Interproximal peri-implant CBL was measured in calibrated digital radiographs. The mucosal thickness was measured based on the digital OPGs in the distal, middle, and mesial areas (Fig 2a). Under infiltrative local anesthesia, an incision in the center of the edentulous alveolar ridge was made, and the buccal flap was carefully reflected. The mucosal thickness of the unseparated palatal-lingual flap was determined with a periodontal probe in the center of the future implant site at the bone crest (Fig 2b). For the same position of the mucosa, radiographic assessment was conducted on OPGs taken before surgery in the crest, middle, and mesial areas, and no statistically significant difference was found between the two measurement methods.

When the implant was positioned above the bone level, the value of the initial biologic width was considered to be the difference between the thickness of the mucosa and the implant above the bone level. When the implant was placed below the bone level, the value of initial biologic width was the sum of the thickness of mucosa and the depth of the implant.

Statistical analysis was performed using SPSS software (SPSS 17.0, SPSS). Intraclass correlation coefficient (ICC) was used to analyze the interexaminer agreement of distance between platforms to the bone level on the first 20 implants for continuous variables. The normality of the numerical variables was checked through the Kolmogorov-Smirnov test. If the data distribution was skewed, the data were analyzed by nonparametric tests. According to the quartile of the initial biologic width, the implants were divided into four groups: groups A, B, C, and D. Meanwhile, all implants were categorized into groups in accordance with the implant depth, the mucosa thickness, and implant systems. The implants were grouped by the placement level relative to the bone crest. In the thin mucosa group, the soft tissue thickness before implant placement was ≤ 2 mm, and in the thick mucosa group, initial soft tissue thickness was > 2 mm. The PD, BOP, and PLI of each implant were recorded with the highest indication. The Mann-Whitney U test was used to analyze quantitative data. The chi-square test was used to analyze qualitative data. $P < .05$ was set as the significance level.

### RESULTS

Bone loss characteristics of 413 dental implants in a total of 266 patients (94 male and 172 female) were
Sun et al included in this study. The mean age of the included patients was 51.43 years, with a range from 22 to 85 years. The samples included 239 Straumann implants and 174 Ankylos implants. The average follow-up was 21.50 months. The patient distributions are displayed in Table 1, and the implant characteristics are listed in Table 2. Typical radiologic images are shown in Fig 3.

<table>
<thead>
<tr>
<th>Implant diameter (mm)</th>
<th>Implant length (mm)</th>
<th>Implant location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Maxillary premolar</td>
</tr>
<tr>
<td>Straumann BL</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>3.3</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>4.1</td>
<td>16</td>
<td>47</td>
</tr>
<tr>
<td>Ankylos</td>
<td>8</td>
<td>9.5</td>
</tr>
<tr>
<td>3.5</td>
<td>1</td>
<td>28</td>
</tr>
<tr>
<td>4.5</td>
<td>26</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>No. of implants</td>
<td>200</td>
</tr>
</tbody>
</table>

Fig 3  (a) 24 months after loading with implant below the bone level at thin gingiva. (b) 24 months after loading with implant at the bone level at thin gingiva. (c) 38 months after loading with implant below the bone level at thick gingiva. (d) 22 months after loading with implant at the bone level at thick gingiva.
An ICC of 0.905 (95% CI: 0.866 to 0.933; P < .001) indicated strong agreement between the two examiners (D.Y., X.L.) who measured the distance from the platform to the bone level. Radiographic bone loss values were not normally distributed, as shown by the Shapiro-Wilk test. Greater than 90% of implants in this study experienced no more than 1.0 mm of bone loss (Fig 4). Two implants in the Ankylos group lost more than 2 mm of bone.

According to the quartile of the initial biologic width, the implants were divided into four groups: group A (≤ 2.85 mm, n = 104), group B (2.85 to 3.40 mm, n = 103), group C (3.40 to 3.97 mm, n = 104), and group D (> 3.97 mm, n = 102). The bone resorption for group A was significantly greater than the CBL for group B, with a median of 0.38 mm for group A and a median of 0.25 mm for group B (P = .003). The median CBL of group B was significantly higher than that of group C (0.40 mm; P = .003). No differences were observed for the CBL of group C and group D (0.40 mm; P > .05).

The average level of marginal bone loss at the time of examination was 0.35 mm. Specifically, the bone loss values were 0.30 mm for Straumann BL and 0.40 mm for Ankylos. There was no statistically significant difference between the two implant systems (P > .05); meanwhile, PD, BOP, and PLI did not reach a statistically significant difference between the two systems (P > .05). PD, BOP, PLI, and CBL for the two systems are presented in Table 3. No statistically significant differences in relation to PD, BOP, and PLI were observed between thin and thick mucosa or different insertion levels. The CBL was 0.50 mm in the thin mucosa group and 0.30 mm in the thick mucosa group (P < .000). In contrast, when implants were placed even with the bone level, the CBL was 0.10 mm; when implants were placed below the bone level, the CBL was 0.50 mm (P < .000). PD, BOP, PLI, and CBL for different gingival thicknesses and implant positions are shown in Table 3.

**DISCUSSION**

This retrospective study mainly investigated CBL and soft tissue states around dental implants in different initial biologic widths after a follow-up of nearly 1 to 5 years. The results displayed that the initial biologic width of the implant could influence the peri-implant CBL.

This study demonstrated that when the initial biologic width of the implant was between 2.85 and 3.40 mm, less CBL around the implant was observed. This particular value was close to the implant biologic width. The dimensions of biologic width around submerged implants ranged from 3.42 to 3.80 mm. Why did the initial biologic width in the present study result in the minimum amount of CBL, and why was it smaller than that reported in other studies? The present authors mainly speculated three reasons. First, the present study had set the initial vertical depth (3 to 4 mm) for later biologic width forming during the implant placement. Namely, a patient with thin gingival phenotype may form 3 mm biologic width after healing. It included vertical gingiva thickness of 1 mm and subcrestal bone height of 2 mm. Second, during stage two of the operation, the mucosa thickness will be increased appropriately during the process of incising the
Table 3 Demographic and Clinical Parameters for Different Implant Groups

<table>
<thead>
<tr>
<th></th>
<th>Straumann × Ankylos</th>
<th>Gingival thickness</th>
<th>Bone level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Thinner</td>
<td>Thicker</td>
</tr>
<tr>
<td>No. %</td>
<td>No. %</td>
<td>No. %</td>
<td>No. %</td>
</tr>
<tr>
<td>PD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PD &lt; 4</td>
<td>187</td>
<td>75.4</td>
<td>89</td>
</tr>
<tr>
<td>PD ≥ 4</td>
<td>61</td>
<td>24.6</td>
<td>27</td>
</tr>
<tr>
<td>BOP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>100</td>
<td>38.2</td>
<td>48</td>
</tr>
<tr>
<td>1</td>
<td>148</td>
<td>61.8</td>
<td>68</td>
</tr>
<tr>
<td>PLI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>120</td>
<td>49.0</td>
<td>51</td>
</tr>
<tr>
<td>1</td>
<td>116</td>
<td>47.3</td>
<td>57</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>3.7</td>
<td>7</td>
</tr>
<tr>
<td>CBL (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Med P25,P75</td>
<td>0.35</td>
<td>0.05,0.65</td>
<td>0.30</td>
</tr>
</tbody>
</table>

PD = probing depth; BOP = bleeding on probing; PLI = Plaque Index; CBL = crestal bone loss; Med = median; P25 = 25th percentile; P75 = 75th percentile.

*P < .05 (chi-square test). **P < .05 (Mann-Whitney U test).

gingiva from the central alveolar ridge and pushing the gingiva to both sides. Third, the emerging profile of the healing cap or prosthesis can reshape the gingiva and local morphology.

Only a few clinical studies investigated both the influence of soft tissue thickness and the effects of depth of the implant at the same time.20,27 Linkevicius et al evaluated these two factors in a 1-year prospective controlled clinical trial. The implants in the test group were placed 2 mm supracrestally, while the control group was placed equicrestally. The findings indicated that CBL was higher if the tissue thickness was ≤ 2.0 mm, compared with soft tissue > 2.0 mm thick, despite the supracrestal or equicrestal position of the implant-abutment interface.27 Vervaeke et al investigated the impact of soft tissue thickness and the vertical position of the implant on CBL around the implants. By adjusting the vertical position of the implant according to the thickness of the mucosa, establishing the expected biologic width might prevent unexpected CBL around the implant. Otherwise, the risk of the exposure of the implant neck and peri-implant pathology would increase.20

Although crown composition and structure are similar in dental implants and natural dentition,12,40 the attachment parameter is longer around dental implants than around natural dentition.3 Subsequently, more soft tissue space around the implant is required. If it is not sufficient, CBL will occur until there is sufficient space for soft tissue.25 Studies have shown that the marginal bone was stable within a constant vertical distance from the microgap.33,41 It is suggested that a certain width of soft tissue enables an appropriate epithelial-connective tissue attachment to protect osseointegration.11,25 This can explain why PD in the follow-up showed no statistical difference between groups. Supracrestal connective tissue attachment would occur around the polished transmucosal part of the abutment and form a biologic width to protect the marginal bone.33

The results of the present study showed that the median CBL around implants was 0.35 mm, specifically 0.30 mm for Straumann BL and 0.40 mm for Ankylos after 1 to 5 years of follow-up. These results were similar to other clinical studies evaluating the same implant systems, which reported CBL of 0.30 to 0.45 mm for Straumann BL18 and 0.50 to 1.84 mm for Ankylos.17,42,43

Kütan et al13 documented that shallow implant insertion caused less resorption in comparison with deeper insertion, which is consistent with the results of this study. Jung et al examined the bone levels of implants placed at different depths in the jaws and reported that the group of implants placed 1 mm below the bone level showed the highest CBL.14 In addition, Pontes et al23 and Yi et al15 reported similar conclusions that marginal bone changes were dependent on the vertical positions of implants. According to previous reports, the increased bone absorption of implants below the bone level might be due to bacterial colonization, inflammatory infiltration at the implant-abutment junction, and closed hyoxia environment.44–46

In this study, the effect of mucosal thickness on CBL was estimated. The CBL of implants in the thick mucosa group was less than that of implants in the thin mucosa group. Berglundh et al reported in an animal study that they reduced mucosa thickness in the test group and observed that bone resorption could establish the same biologic width as in the thick mucosa group, but
at a more apical position. They concluded that there was a certain minimum thickness of the mucosa around the implant, which was a prerequisite for stable soft tissue attachment formation. A recent systematic review and meta-analysis demonstrated that implants placed with a thicker gingival biotype had less radiographic CBL, and soft tissue thickness of more than 2 mm was required for the establishment of the biologic width. Even if an implant with platform switching was used, the crestal bone around the implant could not be retained on the thin soft tissue. Consequently, implants seated at sites with thin soft mucosa have a high percentage of unexpected peri-implant bone loss. As a possible solution, some investigators suggest soft tissue thickening before or during implant placement to reduce CBL. However, recent studies also pointed out that excessive vertical thickness of soft tissue was related to the increased CBL. There were also studies showing that there was no positive effect of the influence of mucosal thickness on CBL of platform-switching implants. The results of this study would help develop the guidance for clinical practitioners of dental implant procedures to minimize alveolar CBL around dental implants. Although implants below the bone level in the thin mucosa will cause more bone resorption, this can meet the needs of biologic width and maintain the relative stability of the gingival height. This method can avoid the risk of implant neck exposure caused by receding gums.

In this study, mucosa thickness was measured based on radiographs. In a large number of similar studies, mucosa thickness was measured directly by periodontal probing. The present authors did a preliminary experiment and compared the gingival thickness of the posterior teeth on the oral panoramic radiograph with the ginvial thickness measured directly by periodontal probing. No statistical difference was found between the two groups. Therefore, the mucosal thickness measurement of posterior teeth based on oral panoramic radiographs can be an efficient way for a retrospective study to access a large amount of data.

Some limitations should be considered in the findings of this study. The use of panoramic radiographs is a major limit of this study. Periapical radiographs and CBCT have higher imaging accuracy than panoramic radiographs. However, due to the limitation of actual conditions, panoramic radiographs were used as the radiographic evaluation in this study. The digital radiography technique was used to introduce the radiographs, and the measured data were corrected with the known implant length. This makes the accuracy of panoramic radiographs acceptable.

Because this was a retrospective study, many influencing factors were involved. According to the reported research, many factors will affect the peri-implant bone loss, such as surface roughness, the timing of starting the load, platform switching, and restoration. Factors such as implant design and the timing of starting the loading were controlled in this study. However, the restoration design or patient-related factors cannot be controlled.

Another limitation could be the span of the study (1 to 5 years). Differing observation times will result in possible errors. Biologic width will reestablish in 6 to 8 weeks and remain stable over time. Therefore, the present observational time is long enough to cover the CBL caused by the formation of biologic width. However, further studies are necessary for better understanding of this step in the process.

CONCLUSIONS

The initial biologic width has an effect on CBL. Based on radiographic evaluation, the crestal bone level around implants placed in thick gingiva and even with the bone level showed better stability compared with implants placed in thin gingiva and below the bone level.

ACKNOWLEDGMENTS

This study was jointly supported by the Key Research and Development Program of Science and Technology Department of Zhejiang Province (No. 2019C03081), Zhejiang Medical and Health Science and Technology Project, China (No. 2020KY625), Fundamental Research Funds for the Central Universities 2020FZZX008-08, and Zhejiang Provincial Natural Science Foundation (No. LQ21H140001). The authors declare that no conflict of interest exists in relation to this project.

REFERENCES


