# THE INFLUENCE OF THE DISTANCE BETWEEN NARROW IMPLANTS AND THE ADJACENT TEETH ON MARGINAL BONE LEVELS


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**Keywords**: Narrow, Small diameter, Implant, Incisor, Marginal bone loss

## ABSTRACT

**Objective**: To investigate how the distance between narrow implants and adjacent teeth influences the marginal bone levels (MBL) up to 3 years after placement.

**Material and Methods**: A prospective, single arm, multi-center clinical study was designed to include patients missing 12, 22, 32, 31, 41 or 42 teeth. Implants of 3.0 mm diameter and different lengths were used in the study. One-stage surgery was performed and healing abutments placed during the 6 to 10 weeks healing period. Clinical and radiographic evaluation was done at implant installation, loading, and at the 6, 12, 24 and 36-months follow-up visits.

**Results**: Eighty-three implants were placed in 59 patients. 48 implants were placed in narrow implant-to-tooth spaces (percentile 25, 0.83(0.25)mm), 80 in regular spaces (percentile 25<x<75, 1.59(0.26)mm) and 47 in wide spaces (percentile 75, 2.61(0.51)mm). Implant MBL change from restoration delivery to 36 months was of 0.50(0.79), 0.50(0.98) and 0.00(0.55) mm in the narrow, regular and wide distance groups (p=0.005, Mann-Whitney U test). Changes in MBL on the adjacent teeth were not significant.

**Conclusion**: The distance between narrow diameter implants and the adjacent teeth does not influence the marginal bone levels neither at the implant or the tooth side. In the current study, less marginal bone loss occurred in the narrower spaces.

# INTRODUCTION

Upper lateral and lower incisor are the smallest mesio-distal teeth, in particular in Caucasian population (Hanihara & Ishida 2005). Once lost, their replacement using dental implants is challenging because of the limited space between adjacent abutment teeth. The limited space may not allow the placement of a standard diameter implant without the risk of implant thread exposure (Romeo et al. 2006), damage on the periodontal ligament of the adjacent teeth and interproximal bone (Cardaropoli et al. 2006) or the loss of the marginal bone of the implant and the crest in contact with the tooth (Choquet et al. 2001; Gastaldo et al. 2004; Grunder et al. 2005; Tarnow et al. 2000, 1992; Tarnow & Eskow 1995). A distance greater than 1.5 mm to the adjacent tooth has been accepted as the minimum to avoid these complications (Grunder et al. 2005).

The use of narrow diameter implants could reduce the risks by limiting the space occupied by the implant itself. Several types have been used over the last decade. Narrow implants are generally considered as those with a diameter of 3–3.4 mm (Quek et al. 2006), and comparable between different implant systems (Avila et al. 2007). Long-term success of narrow diameter implants has been reported to be lower than when using standard diameter implants (Albrektsson et al. 2007; Ortega-Oller et al. 2014; Renouard & Nisand 2006; Romeo et al. 2006; Winkler et al. 2000). It has been discussed that those lower success rates might be related to implant location, bone density, combination with short lenghts (<8mm) and lower biomechanical properties of narrow implants (Romeo et al. 2006). Some reports however indicate better results ranging from 90 to 100% before loading (Reddy et al. 2008; Vigolo et al. 2004; Vigolo & Givani 2000; Zarone et al. 2006) and similar with long-term follow-ups (Andersen et al. 2001; Block & Kent 1993; Cordaro et al. 2006; Degidi et al. 2008; Hallman 2001; Lee et al. 2013; Saadoun & Le Gall 1996; Sohrabi et al. 2012; Zinsli et al. 2004; Zweers et al. 2015).

The versatility of a two-piece narrow implant that allows for different prosthesis designs has proven successful (Galindo-Moreno et al. 2012; Maiorana et al. 2015), with implant survival rates after 12 years higher than 98% (Lee et al. 2013). However, in many cases, the available interdental space, even for a 3 mm diameter implant can be limited and result in less than 1.5mm distance being available between the implant and adjacent teeth. In such circumstances, little is known about the marginal bone loss over time surrounding narrow diameter implants, despite being considered of high importance for implant success and long-term survival (Galindo-Moreno et al. 2015b).

The aim of this study was to evaluate the influence of the distance between implants and adjacent teeth with that of the marginal bone height around narrow diameter implants up to 3 years after placement.

# MATERIAL AND METHODS

## Study design

This study was originally designed as a prospective, single arm, international multicentre study to recruit patients in need of single tooth replacement in positions 12, 22, 32, 31, 41 or 42 (FDI).

Ethics committees at the University of Granada (YA-NAR-001), the University of Ulm (137/08), the University Hospital (Copenhagen, Denmark) (H-D-2007-0122), The Institute for Postgraduate Education (Jönköping, Sweden) (M20-08), the National Research Ethics Service (08/H0206/24) and the University of Milan (YA-NAR-001) approved the study before it began. The study was registered on http://www.clinicaltrials.gov from the US National Institutes of Health, identified as NCT00646113, from March 25, 2008. All patients received detailed oral and written information on the study and signed a written consent.

## Participants

Before being included in the study patients had to fulfill the following criteria: good general health, smoking ≤ 10 cigarettes per day, absence of oral and dental disorders, single tooth loss with healthy neighboring teeth in normal occlusion, recipient sites for implants that had healed for 2 months following tooth extraction (immediate implant placement was allowed after extracting a primary tooth). Only one study implant per patient was installed, except for patients missing both contra laterals, where both positions were allowed to be treated with study implants.

## Procedures

One hour before the surgery for implant placement, patients received antibiotic prophylaxis (2 g Amoxicillin or 600 mg Clindamycin). After local anesthesia, incisions were made at the neighboring teeth, connected by a crestal incision over the edentulous area and flaps released to expose the bone ridge. The implants were then installed according to the manufacturer instructions. The final drill (diameter of 2.7 mm or 2.85 mm or 3.00 mm) to prepare the implant bed was chosen by the surgeon depending on the bone quality on a case-by-case basis. The implants used in the current study were OsseoSpeed™ TX 3.0S (Astra Tech Implant System, Dentsply Implants, Mölndal, Sweden) 3.0 mm diameter with lengths of 11, 13 and 15 mm. The surgeon determined implant length from case to case. All implants were placed at the buccal plate level. No osteotome or grafting procedure was allowed, except for covering visible implant threads with autogenous bone chips harvested during surgery. Transmucosal healing abutments were then installed and the flaps sutured around them. Subjects received postoperative instructions and were recommended to use a chlorhexidine 0.1 or 0.12% mouth-rinse, twice a day for 10 days after surgery. Sutures were removed 7–13 days after implant surgery.

Dental impressions were taken 5 – 7 weeks after implant installation and 6 – 10 weeks after implant installation the permanent metal-ceramic restoration was cemented on an individually modified 3.0 mm titanium transmucosal abutment (TiDesign™, Dentsply Implants) installed according to the manufacturer instructions after cleaning in an ultrasonic unit and sterilized by steam sterilization with a pre-vacuum cycle at 134°C for 3 minutes.

## Variables: Clinical and radiological examinations

Clinical and radiological examinations were conducted at implant installation, placement of the crown, and at 6, 12, 24 and 36-month follow-up visits. Patient's age, gender and smoking habits as well as implant position, reason for edentulism, bone quality and quantity, grafting, final drill diameter and implant length were recorded.

Intraoral radiographs were taken with a parallel technique using the study sites equipment. To minimize potential bias, an independent experienced radiologist unaware of the study objective analyzed all intraoral radiographs. Total distance between adjacent teeth (TT=tooth-to-tooth distance) was defined as the perpendicular distance between adjacent teeth to the study position at the level of the marginal bone before implant placement. Similarly, distance to adjacent teeth (IT=implant-to-tooth distance) was the distance to the adjacent teeth perpendicular to the reference point on the implant (the junction between the machined bevel and the micro threads) immediately after implant placement. Marginal bone levels (MBL) were determined as the distance from the mesial and distal interproximal bone to the corresponding reference point (cemento-enamel junction for teeth and the junction between the machined bevel and the micro threads for implants) at the designated time points. Finally, MBL change from restoration delivery to the designated time point was defined as gain if a positive value was obtained or loss if negative. Both MBL and MBL change were calculated for implants and adjacent teeth at the mesial and distal sides. **Figure 1** depicts the reference points for each measurement.

## Statistical methods

The current study reports on a secondary analysis of a cohort previously reported (Galindo-Moreno et al. 2012; Maiorana et al. 2015). For this study, patients with measurable x-rays from all relevant time points were included.

Measurements were divided in groups according to the percentile distribution of the total distance between adjacent teeth. Secondly, to further analyze the data and the influence of the thickness of the surrounding bone, new groups according to the actual distance between implants and adjacent teeth were created. In this case, both mesial and distal distances were used, with no respect to patient and position. In both cases, percentiles $<25$ (narrow), $25<x<75$ (regular) and $>75$ (wide) were used. Data is presented as mean (standard deviation).

The statistical software used was IBM SPSS (IBM Corp., Armonk, NY).

For MBL data the Kruskal-Wallis test was used when comparing all three percentile groups at the same time. In comparisons between two specific percentile groups the Mann-Whitney U test (equivalent to Wilcoxon Rank Sum test) was used. All p-values presented are two-sided. Nominal p-values are presented and p-values less than 5% are called “statistically significant”. However, as multiple tests are performed careful interpretations are necessary. No formal adjustment for multiplicity has been applied.

# RESULTS

A total of 59 patients (29 males, 30 females, mean age 32.47(15.63)) with 83 implants have been included in this study (**Table 1**). A study timeline and flow chart are presented in **Figure 2**.

All patients received one or two OsseoSpeed™ TX 3.0S implants in positions 12, 22 and 32 to 42 (FDI). No implants in this population were lost. Global average MBL change for both the implants and the adjacent teeth are represented in **Figure 3**. Patient’s age, gender and smoking habits as well as implant position, reason for edentulism, bone quality and quantity, grafting, final drill diameter and implant length were found to be homogenously distributed among tooth-to-tooth and implant-to-tooth percentiles.

When analyzing the data by the distance between both adjacent teeth, a total of 24 implants were placed in narrow spaces (minimum to maximum=3.2-5.54mm, mean (SD)=4.85(0.59)), 38 in regular (5.55-7.14mm, 6.32(0.45)) and 21 in wide (7.15-10mm, 8.07(0.87). Average implant MBL was 0.50(0.76), 0.30(0.53) and 0.30(0.40) mm at implant placement and 0.30(0.36), 0.30(0.27) and 0.80(1.37) mm at 36-months for the narrow, regular and wide groups, respectively (**Table 2**). To further analyze the evolution of MBL over time, the MBL changes from restoration delivery to each time point were calculated. Average implant MBL change was 0.20(0.70), 0.30(0.57), and 0.40(1.41) mm at implant placement and 0.50(0.92), 0.40(0.73) and 0.00(0.56) mm at 36-months for the narrow, regular and wide groups, respectively (**Figure 4A and Table 2**). These changes were statistically significant only at 36-months (p=0.026, Mann-Whitney U test), more specifically on distal sides (p=0.016, Mann-Whitney U test). However, Kruskal-Wallis test was not significant so these results must be considered as an interesting finding/question for further investigation/corroboration in other/future studies. Changes in adjacent teeth MBL were not significant on any of the groups (-0.03(0.94), 0.04(0.74) and 0.35(0.94) mm at 36-months for the narrow, regular and wide groups, respectively (**Figure 4B and Table 2**).

In addition, MBL and MBL change (both at the mesial and distal aspects of implants and adjacent teeth) were also classified by the distance from the implant to the adjacent tooth at implant placement on that particular mesial or distal side. Similarly, the groups were: narrow (48 implant sides, minimum to maximum=0.30-1.14mm, mean (SD)=0.83(0.25)), regular (80 implant sides, 1.15-2.04mm, 1.59(0.26)) and wide (47 implant sides, 2.05-4.10mm, 2.61(0.51)). The implant MBL was of 0.40(0.66), 0.30(0.78) and 0.30(0.60) mm at implant placement and 0.40(0.45), 0.30(0.46) and 0.70(1.31) mm at 36-months for the narrow, regular and wide groups, respectively (**Table 3**). Average implant MBL change was 0.40(0.80), 0.30(0.66), and 0.40(1.46) mm at implant placement and 0.50(0.79), 0.50(0.98) and 0.00(0.55) mm at 36-months for the narrow, regular and wide groups, respectively (**Figure 5A and Table 3**). These differences were statistically significant at 6-months (narrow vs. wide, p=0.031, and regular vs. wide, p=0.014, Mann-Whitney U test) and at 36-months (narrow vs. wide, p=0.003, and regular vs. wide, p=0.005, Mann-Whitney U test). Differences between narrow and regular spaces were not significant at any of the time points. As when grouped by tooth-to-tooth distances, adjacent teeth MBL changes were not statistically significant when grouped by implant-to-tooth distance (0.00(0.96) mm, 0.00(0.77) mm, and 0.20(0.93) mm for narrow, regular and wide implant-to-tooth distances, respectively) (**Figure 5B and Table 3**).

## DISCUSSION

Narrow diameter implants are defined as those of 3-3.4 mm (Quek et al. 2006). Supporting literature on the survival of these implants is abundant for different indications (Cho et al. 2007; Zarone et al. 2006; Zinsli et al. 2004) and time points (Lee et al. 2013; Sohrabi et al. 2012; Vigolo et al. 2004). However, despite the benefits of their use, specifically in single-tooth restoration in the upper lateral incisor and the lower incisor regions, the long-term success should not only be evaluated in terms of survival but also the stability of the surrounding tissues. This should be considered since it is not only important for the success itself but can also determine future complications (Galindo-Moreno et al. 2015b).

Marginal bone loss (MBL) is used as an important indicator for the health of the peri-implant tissues. In the past, peri-implant bone loss of 1.5-2 mm during the first year after loading was used as a criterion of success and considered as normal in consensus statements and several clinical studies (Albrektsson et al. 1986; Misch et al. 2008; Papaspyridakos et al. 2012; Roos-Jansåker et al. 2006; Tarnow et al. 2000). However, more recently, this measure has been questioned. Implants with increased marginal bone loss rates at early stages (healing and immediate post-loading periods) were more likely to reach MBL values that compromise their final outcome after 18 months (Galindo-Moreno et al. 2015b). Therefore, factors that influence peri-implant bone loss at early stages are of great importance. The available literature has shown a key role of implant diameter, length and depth with respect to the bone crest (Liaje et al. 2012; Zweers et al. 2015), prosthesis design (Anitua et al. 2015), bone quality, soft tissue-related factors, smoking and oral hygiene habits, age and gender (Negri et al. 2014), bone quantity, final drill during implant placement, healing time before prosthesis delivery (Galindo-Moreno et al. 2012) as well as platform switching (Canullo et al. 2010, 2011, 2012) and prosthesis abutment height (Galindo-Moreno et al. 2014, 2016) and connection design (Galindo-Moreno et al. 2015a). A summary of this evidence shows that narrow diameter implants that are placed below the crestal bone in patients who smoke, with under-preparation of the implant bed and restored with individually cemented-crowns soon after they are placed, are more likely to lose more marginal bone in the early stages. This is particularly the case if they have external abutment connection and/or no platform-switching is performed. However, longer-term follow up studies have shown different trends than what could be expected. Some studies using the same implant system as in the current study have found similar marginal bone loss to that of standard implants, regardless of smoking, bone quality, implant length and bone grafting after 3 years of early loading (Galindo-Moreno et al. 2012; Maiorana et al. 2015). Studies with longer follow-up periods have shown similar results with as little as 0.69(0.28) mm of marginal bone loss after 10 years and survival rates irrespective of patients' sex, age, smoking, parafunctional habits, bone type, prosthetic restoration, or implant location, position, or length (Mangano et al. 2014). This would suggest that other variables play a role in MBL changes over time in addition to the previously mentioned variables.

Narrow diameter implants are usually placed where mesio-distal space is compromised. Upper lateral incisors and lower incisors are the smallest teeth in the mesio-distal dimension, especially in Caucasian populations (Hanihara & Ishida 2005) and as a consequence the most common location for the placement of narrow diameter implants. However, in these locations there are occasions in which even narrow diameter implants do not allow for the maintenance of a 1.5mm safety distance to the adjacent teeth. To do so, a mesio-distal interdental space of 6 mm (1.5 mm mesial to the implant + 3 mm for the implant + 1.5 mm distal to the implant) would be required. In the population used for this study, 25% of the patients presented with an interdental space less than 5.5 mm (i.e., less than 1 mm in either side of the implant or both). This patient group provided an opportunity to study the effects of this reduced space on the peri-implant hard and soft tissues. Classically, 1.5mm implant-to-tooth distance was used as a recommended minimal measurement based on the studies by Tarnow et al. (Tarnow et al. 2000) and, more recently, by Gastaldo et al. (Gastaldo et al. 2004) and Grunder et al. (Grunder et al. 2005). Distances lower than 1.5mm were associated with deficiencies effecting the interdental papilla, due in part, to the associated vertical bone reduction around the implant and the adjacent tooth. It was also described that the deeper the implant is placed, the further away from the tooth the implant should be to avoid these complications (Grunder et al. 2005). Most of the studies on this topic however used machined-surface implants which are recognized as having inferior crestal bone osteointegration when compared to today's rough surface implants. In addition, the implant-abutment connections must be considered. The implants used in the current study benefit from an internal conical connection, which has been shown to have one the lowest contamination index of red complex bacteria, although all connections get contaminated (Canullo et al. 2015). Also most of the older implant systems did not benefit from the use of internal connections and the platform-switching concept. These modifications can influence the vertical displacement of the soft tissues and bone surrounding the implant and adjacent teeth. As discussed by Canullo et al. (Canullo et al. 2010), the reasons for the reduced bone loss when placing a prosthetic abutment narrower than the implant might be due to the increase in the available space for the abutment-associated inflammatory cell infiltrate that induces bone resorption (Abrahamsson et al. 1998) due to the formation of what is termed the 'biological width' around the implant (Cardaropoli et al. 2003b). In addition, the surface for soft tissue attachment is also increased (Lazzara & Porter 2006). And, finally, as discussed by Cardaropoli et al. (Cardaropoli et al. 2006) and shown by previous studies (Cardaropoli et al. 2003b), the loss of facial bone would induce a circumferential remodeling to equilibrate the bone level around the implant. By this process, the interproximal marginal bone visible in the radiograph is, therefore, reduced (Wennström et al. 2005). In the present study, no changes on the MBL at the adjacent teeth were found.

Such remodeling process depends, mainly, on the implant design, diameter, and the characteristics of the surrounding bone. Extensive literature has been published on the impact of implant diameter on the cortical bone around the implant neck. Most of them conclude that the use of narrow diameter implants results in an increase of stress and strain around the neck of the implant and the prosthetic connection (Cehreli et al. 2006). This would ultimately induce higher marginal bone loss in comparison with wider implants (Degidi et al. 2008) as predicted by three-dimensional finite-element models (Petrie & Williams 2005). These models even suggested a greater effect of implant diameter than implant length on marginal stress. This results in more than 1 mm of marginal bone loss observed in different studies at different time points and particularly at early stages (Arisan et al. 2010; Cardaropoli et al. 2006; Degidi et al. 2009a b; Maló & de Araújo Nobre 2011; Romeo et al. 2006; Zarone et al. 2006; Zembić et al. 2012). However, an extensive literature review observed no relationship between marginal bone loss and implant diameter (Renouard & Nisand 2006). More recently, a systematic review included 21 clinical studies published between 2002 and 2012 with at least 12 months of follow up. Globally, 2980 narrow-diameter implants in 1607 patients were analyzed. Only 866 implants in 468 patients had lost more than 1 mm of marginal bone (Sierra-Sánchez et al. 2014). Therefore, it could be concluded that the implant diameter itself as a stand-alone factor fails to determine the marginal bone level.

In contrast, the surrounding bone should be the focus of future studies on marginal bone levels, and, in particular, when narrow diameter implants are used. Similar to the classical observations on periodontal surgery, following implant placement with either full or partial-thickness flap, there is a mean facial bone loss of 0.7 mm early on after the surgery (Spray et al. 2000). As mentioned earlier, this loss of facial bone would result in a circumferential leveling around the implant. Therefore, a minimum of 2 mm of facial bone surrounding implants has been proposed as a cut-off point for long-term success and bone coverage (Grunder et al. 2005), although this has not been confirmed by some systematic reviews (Teughels et al. 2009). The reasons for this bone loss can be expected to be similar to those observed after tooth extraction: the lost of the bundle bone. This has been observed in animal (Araújo et al. 2005; Araújo & Lindhe 2009; Cardaropoli et al. 2003a) and clinical studies (Pietrokovski & Massler 1967; Schropp et al. 2003) as a consequence of the lost of functional mechanical stimuli, a fundamental principle of bone physiology (Hansson & Halldin 2012). However, in the space between the implant and the adjacent teeth, this effect will not happen as the tooth is still functional and its periodontal ligament still supporting the bone crest. Therefore, the loss of the strip of bone between the implant and the adjacent tooth should not be expected regardless of its mesio-distal thickness since its maintenance is not due to the implant but the tooth. Moreover, and specifically regarding narrow implants, the bone resorption at the marginal level, as observed in the present study, should also be redefined. As recently shown by Temmerman et al. (Temmerman et al. 2015) evaluating the same implant system as in the present study, the use of 3.5 mm implants in ≤4.5 mm bucco-lingual alveolar crests (<1 mm of bone is surrounding the most coronal part of the implant) does not influence the marginal bone level after 3 years. Therefore, they concluded that the implant design (micro-threads in the conical and marginal part of the implant) and the avoidance of bone compression by a careful drilling to maintain blood supply seem to be more important than the bucco-lingual dimensions of the crest in the maintenance of the marginal bone.

Interestingly, our study appears to demonstrate that the distance between the tooth and the implant is actually inversely proportional to the level of marginal bone loss: the smaller the distance, the smaller the bone loss. However, this finding has to be considered with caution. As of this point, implant placement very close to the tooth to maintain the marginal bone should not be recommended, as the current findings must be confirmed by larger studies in which the potential contribution of other variables need to be evaluated, including age, gender, bone grafting at implant placement, periodontal status, smoking habits, cause of tooth loss, position, final drill or implant length. Moreover, placing the implants close to the tooth may increase the risk of perforating the periodontal ligament space and may induce bone resorption by trauma. Even more, esthetic characteristics and patient's demands should also be analyzed. Therefore, narrow diameter implants in very narrow mesio-distal spaces that result in less than 1.5 mm to the adjacent tooth can be safely used in terms of MBL maintenance but caution must always be taken in such limited spaces.

## CONCLUSION

Results from the current study confirm that the distance from adjacent teeth to narrow diameter implants in the anterior region does not influence the changes in marginal bone level with the use of OsseoSpeed™ TX 3.0 S implants with a conical connection. Moreover, in the current study, less marginal bone loss occurred in the narrower spaces with respect to the adjacent tooth. Changes in the adjacent teeth were not significant.

## DISCLOSURE

This international multicenter study has been fully sponsored by Dentsply Implants. However, none of the researchers have economical interests in the product related in this study or in the company.

## ACKNOWLEDGMENT

The authors want to thank to Mr. Robert Corbé for his help, guidance and monitoring process during this study.

## TABLES

**Table 1**. Overall study data.

| | Absolute value or Mean (SD) |
|---|---|
| Number of patients | 59 |
| Age | 32.47(15.63) |
| Gender | |
| Male | 30 |
| Female | 29 |
| Number of implants | 83 |
| **Implant** | |
| Marginal bone level | |
| Implant placement | 0.40(0.58) |
| Restoration delivery | 0.70(0.98) |
| 6 months | 0.60(0.80) |
| 12 months | 0.40(0.84) |
| 36 months | 0.40(0.75) |
| Marginal bone level change with respect to restoration delivery | |
| Implant placement | 0.30(0.89) |
| 6 months | 0.10(0.73) |
| 12 months | 0.20(0.72) |
| 36 months | 0.30(0.78) |
| **Adjacent tooth** | |
| Marginal bone level | |
| Restoration delivery | 2.00(1.97) |
| 36 months | 1.90(1.92) |
| Marginal bone level change with respect to restoration delivery | |
| 36 months | 0.10(0.87) |

**Table 2**. Marginal bone level analysis considering the distance between adjacent teeth at the time of implant placement.

<table>
<tr><th></th><th>N<br>25 pct</th><th>R<br>25<x<75 pct</th><th>W<br>75 pct</th><th>Significant p values (Mann-Whitney U test)</th></tr>
<tr><td colspan="5">Distance between adjacent teeth</td></tr>
<tr><td>Number of implants</td><td>24</td><td>38</td><td>21</td><td></td></tr>
<tr><td>Mean(SD)</td><td>4.85(0.59)</td><td>6.32(0.45)</td><td>8.07(0.87)</td><td></td></tr>
<tr><td>Min-Max</td><td>3.20-5.54</td><td>5.55-7.14</td><td>7.15-10</td><td></td></tr>
<tr><td colspan="5">Average MBL at the implant (Mean(SD))</td></tr>
<tr><td>Implant placement</td><td>0.50(0.76)</td><td>0.30(0.53)</td><td>0.30(0.40)</td><td></td></tr>
<tr><td>Restoration delivery</td><td>0.80(0.96)</td><td>0.60(0.70)</td><td>0.70(1.37)</td><td></td></tr>
<tr><td>6 months</td><td>0.70(0.65)</td><td>0.50(0.36)</td><td>0.80(1.36)</td><td></td></tr>
<tr><td>12 months</td><td>0.40(0.54)</td><td>0.30(0.33)</td><td>0.70(1.48)</td><td></td></tr>
<tr><td>36 months</td><td>0.30(0.36)</td><td>0.30(0.27)</td><td>0.80(1.37)</td><td></td></tr>
<tr><td colspan="5">Average MBL Change at the implant (Mean(SD))</td></tr>
<tr><td>Implant placement</td><td>0.20(0.70)</td><td>0.30(0.57)</td><td>0.40(1.41)</td><td></td></tr>
<tr><td rowspan="2">6 months</td><td>0.10(0.97)</td><td>0.10(0.69)</td><td>-0.10(0.43)</td><td rowspan="2"></td></tr>
<tr><td colspan="3">Kruskal-Wallis Test: p=0.6646</td></tr>
<tr><td rowspan="2">12 months</td><td>0.30(0.82)</td><td>0.30(0.74)</td><td>0.10(0.53)</td><td rowspan="2"></td></tr>
<tr><td colspan="3">Kruskal-Wallis Test: p=0.3148</td></tr>
<tr><td rowspan="2">36 months</td><td>0.50(0.92)</td><td>0.40(0.73)</td><td>0.00(0.56)</td><td rowspan="2">0.026 (N pct vs. W pct)</td></tr>
<tr><td colspan="3">Kruskal-Wallis Test: p=0.0581</td></tr>
<tr><td colspan="5">Average MBL at the adjacent tooth (Mean(SD))</td></tr>
<tr><td>Restoration delivery</td><td>2.01(1.69)</td><td>1.78(1.71)</td><td>2.14(2.58)</td><td></td></tr>
<tr><td>36 months</td><td>1.89(1.66)</td><td>1.69(1.75)</td><td>2.01(2.45)</td><td></td></tr>
<tr><td colspan="5">Average MBL Change at the adjacent tooth (Mean(SD))</td></tr>
<tr><td>36 months</td><td>-0.03(0.94)</td><td>0.04(0.74)</td><td>0.35(0.94)</td><td></td></tr>
</table>

**Table 3**. Marginal bone level analysis considering each mesial and distal distance between adjacent teeth and the implant at the time of implant placement.

| | N<br>25 pct | R<br>25<x<75 pct | W<br>75 pct | Significant p values (Mann-Whitney U test) |
|---|---|---|---|---|
| Distance between implant and adjacent teeth | | | | |
| Number of sites | 48 | 80 | 47 | |
| Mean(SD) | 0.83(0.25) | 1.59(0.26) | 2.61(0.51) | |
| Min-Max | 0.30-1.14 | 1.15-2.04 | 2.05-4.10 | |
| Average MBL at the implant (Mean(SD)) | | | | |
| Implant placement | 0.40(0.66) | 0.30(0.78) | 0.30(0.60) | |
| Restoration delivery | 0.80(0.91) | 0.70(0.94) | 0.70(1.29) | |
| 6 months | 0.70(0.86) | 0.50(0.59) | 0.90(1.31) | |
| 12 months | 0.50(0.69) | 0.30(0.44) | 0.70(1.42) | |
| 36 months | 0.40(0.45) | 0.30(0.46) | 0.70(1.31) | |
| Average MBL Change at the implant (Mean(SD)) | | | | |
| Implant placement | 0.40(0.80) | 0.30(0.66) | 0.40(1.46) | |
| 6 months | 0.00(0.86) | 0.20(0.91) | -0.20(0.54) | 0.031 and 0.014 (N vs. W and R vs. W, respectively) |
| | Kruskal-Wallis Test: p=0.0275 | | | |
| 12 months | 0.30(0.71) | 0.40(0.99) | 0.00(0.49) | |
| | Kruskal-Wallis Test: p=0.2184 | | | |
| 36 months | 0.50(0.79) | 0.50(0.98) | 0.00(0.55) | 0.003 and 0.005 (N vs. W and R vs. W, respectively) |
| | Kruskal-Wallis Test: p=0.0048 | | | |
| Average MBL at the adjacent tooth (Mean(SD)) | | | | |
| Restoration delivery | 2.10(1.62) | 1.90(1.96) | 2.00(2.27) | |
| 36 months | 2.20(1.75) | 1.70(1.76) | 2.00(2.36) | |
| Average MBL Change at the adjacent tooth (Mean(SD)) | | | | |
| 36 months | 0.00(0.96) | 0.00(0.77) | 0.20(0.93) | |

## Figure Legends

**Figure 1**. Diagram depicting the reference points for each measurement.

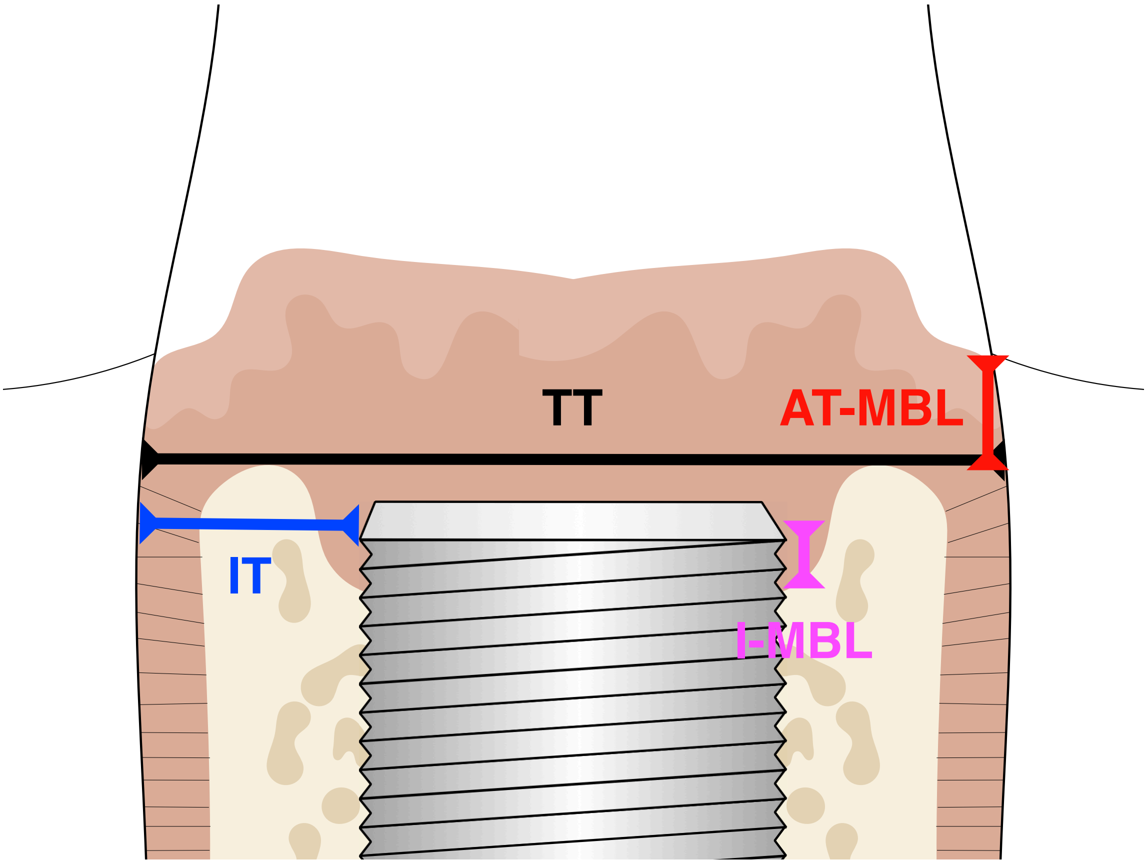


**Figure 2**. A) Study time line and B) flow chart of the included patients.

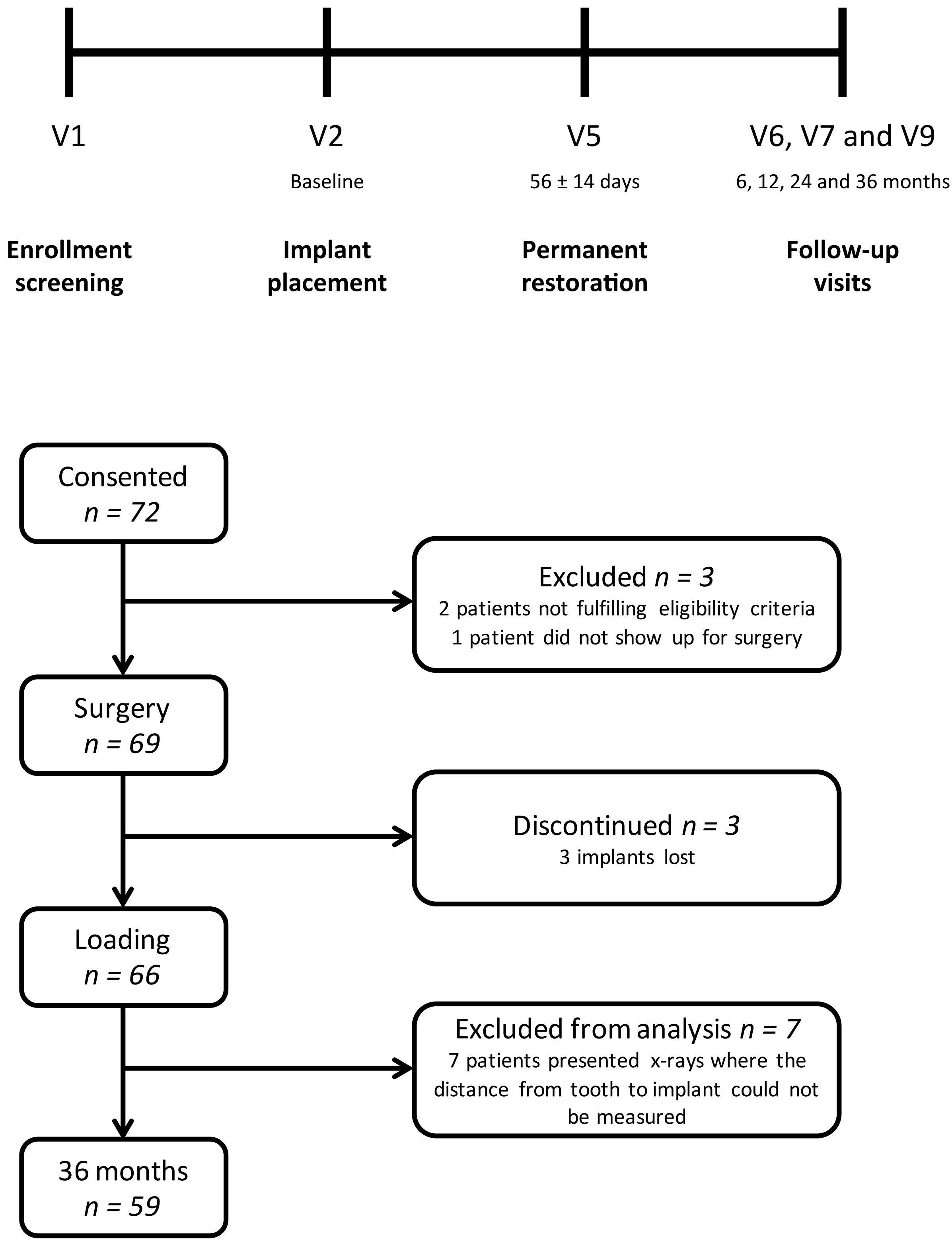
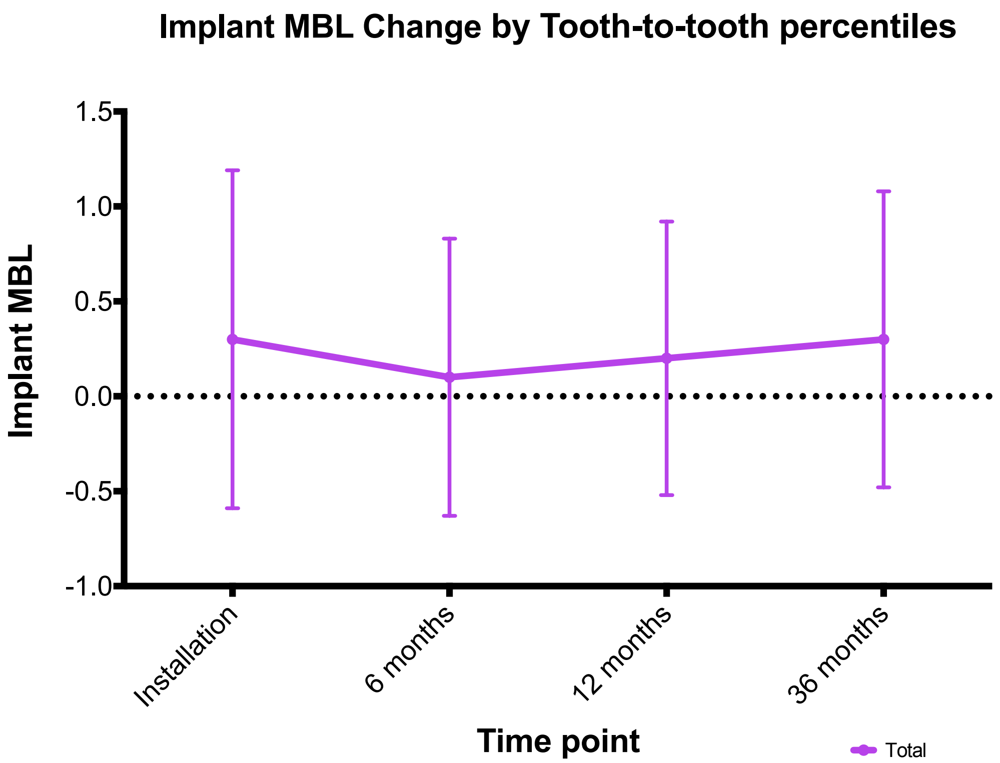
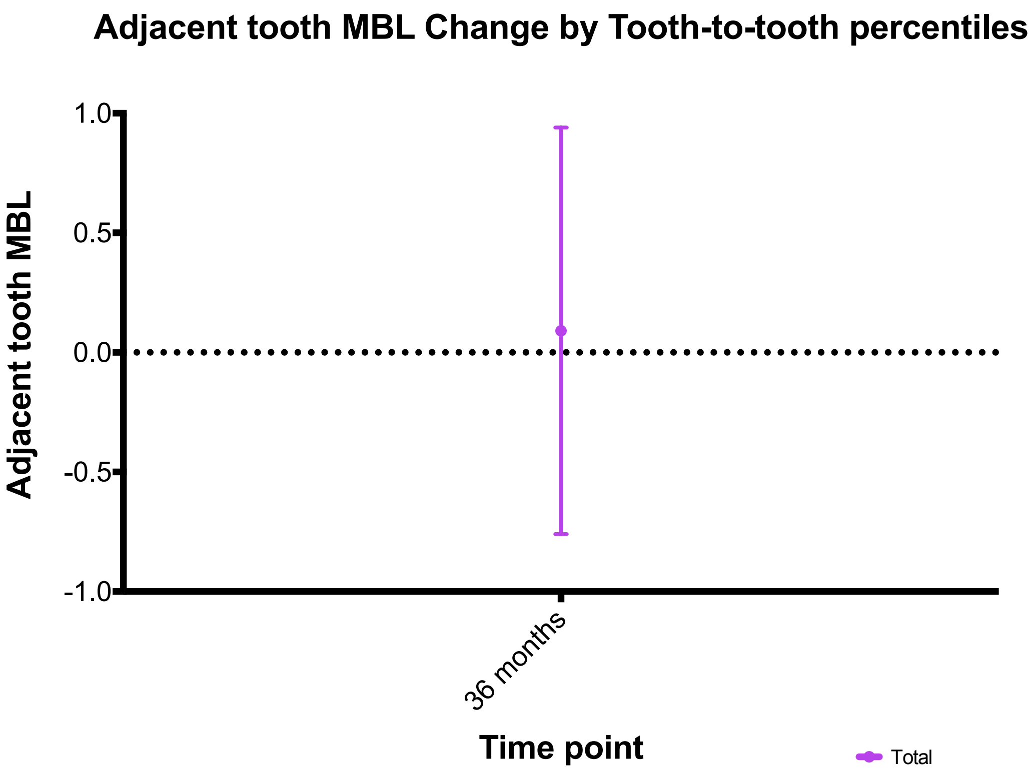


**Figure 3**. Global average MBL change for A) the implants and B) the adjacent teeth. Error bars represent SD. Note that no percentiles are represented here but the overall changes.

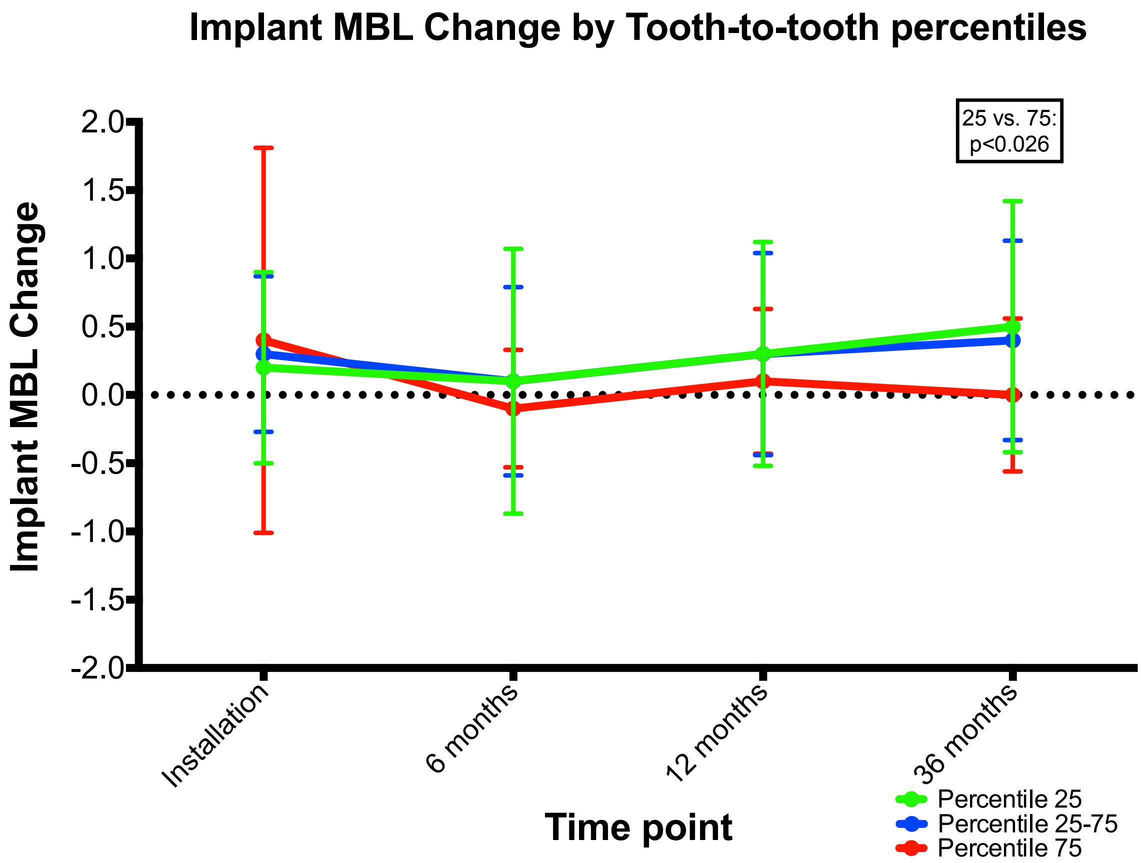



A)

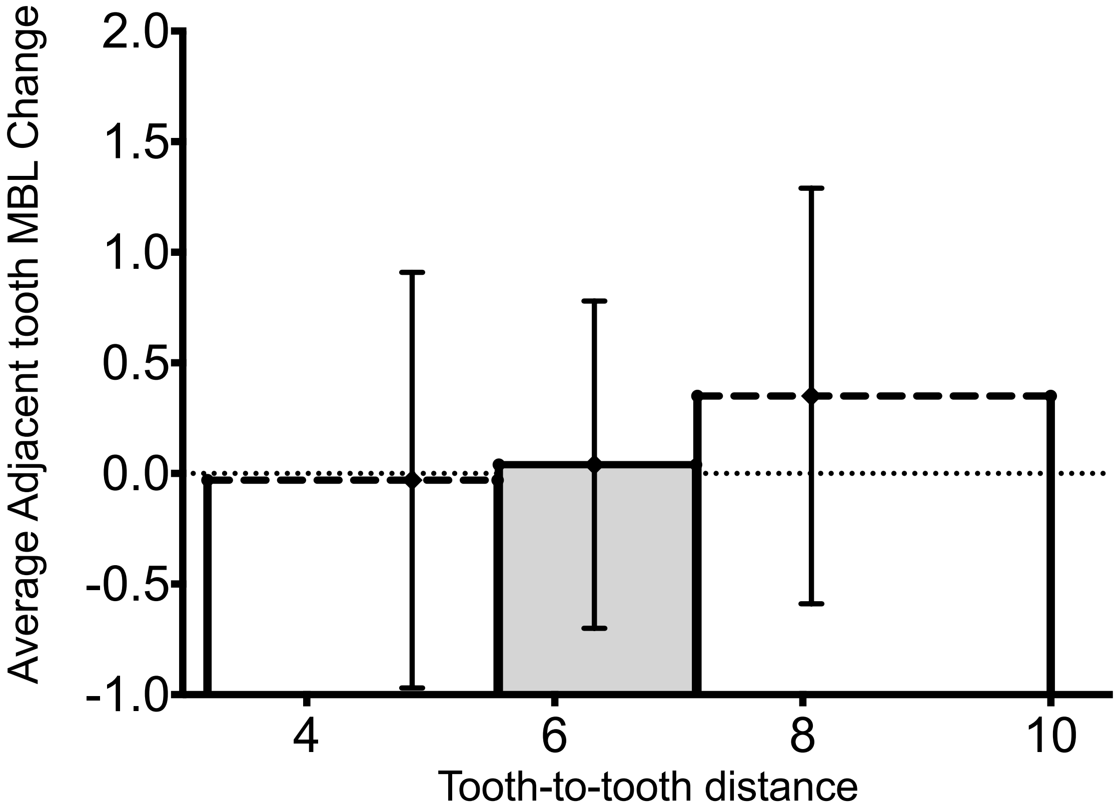



B)

**Figure 4**. A) Average of MBL changes at the implant shoulder from restoration delivery to each time point by percentiles of distances between teeth surrounding the implant under study. B) MBL change at the adjacent teeth from restoration delivery to 36-months by percentiles of distances between teeth. Column width represents the range between minimum and maximum distance while column height represents the MBL change (positive values represent gain of marginal bone and negative values represent loss). Standard deviation bars are located at the average distance between teeth when projected on the x-axis.

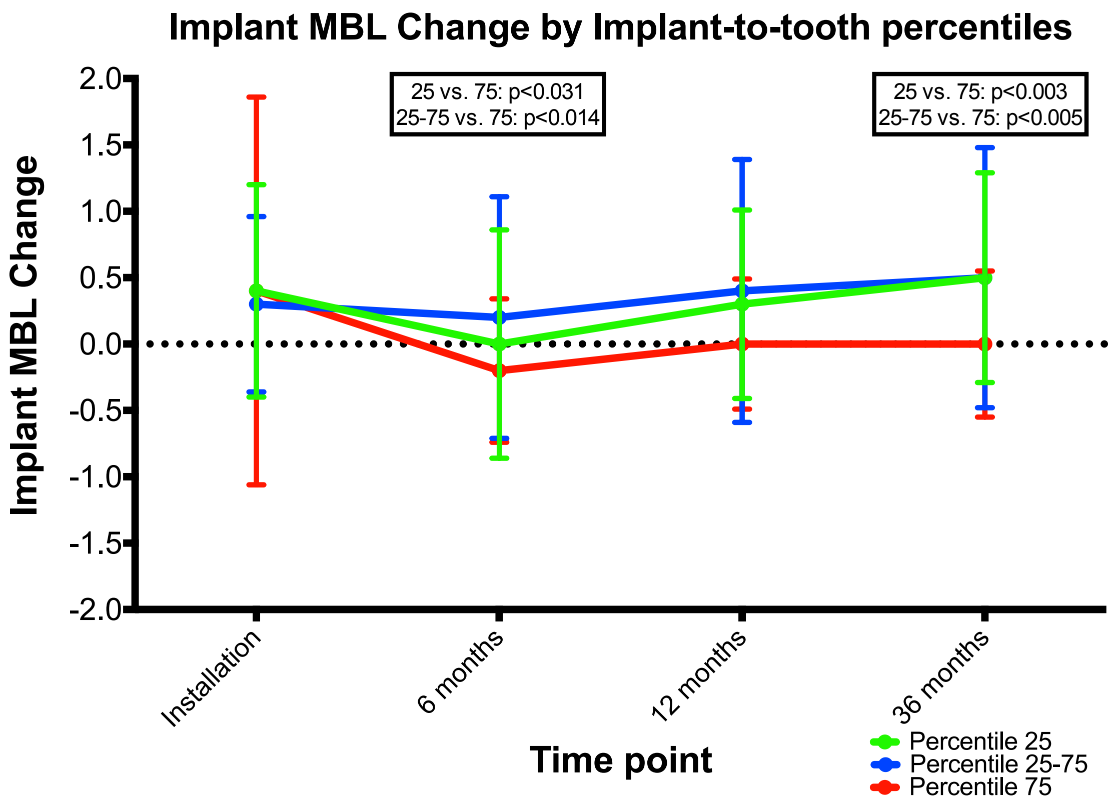



A)

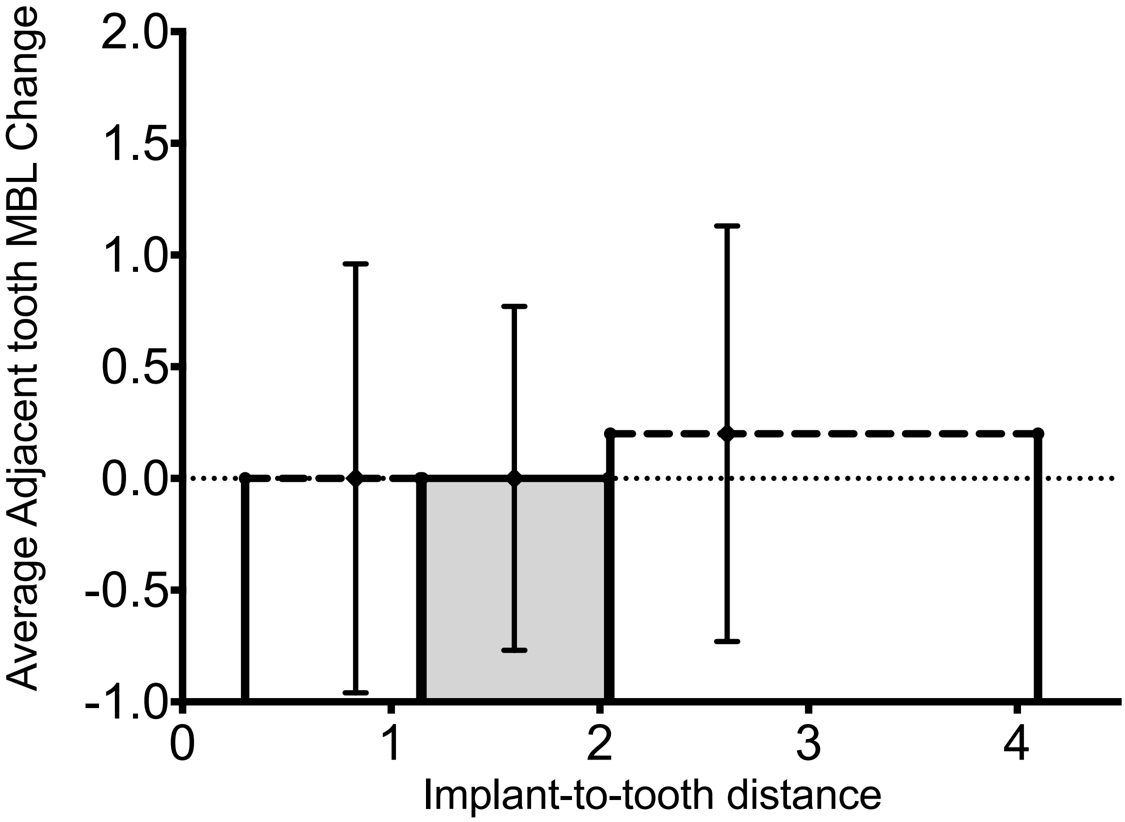

Average Adjacent tooth MBL Change
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
4
6
8
10
Tooth-to-tooth distance

B)

**Figure 5**. A) Average of MBL changes at the implant shoulder from restoration delivery to each time point by percentiles of distances between teeth surrounding the implant and the implant itself. B) MBL change at the adjacent teeth from restoration delivery to 36-months by percentiles of distances between teeth and implants. Column width represents the range between minimum and maximum distance while column height represents the MBL change (positive values represent gain of marginal bone and negative values represent loss). Standard deviation bars are located at the average distance between teeth when projected on the x-axis.




A)


Average Adjacent tooth MBL Change
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
0
1
2
3
4
Implant-to-tooth distance

B)

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