



The Relative Occlusal Forces of Single Posterior Implant-Supported Fixed Prostheses: a Prospective Pilot Study

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Abstract

This prospective pilot study focused on the relative occlusal forces of implant prostheses in differently designed implant occlusion. It aimed to analyze the relative occlusal forces of single posterior implant-supported fixed prostheses over time by the T-scan system and compare the marginal bone loss of single posterior implant-supported fixed prostheses over time. Twelve patients who needed a single posterior implant-supported prosthesis were randomly divided into two groups which were Implant-protected occlusion (IPO) and LOAD groups. All patients were received with implant treatment protocol according to the faculty standard. However, the implants in the IPO group presented with occlusal contact at the heavy bite and no occlusal contact at the light bite. While for the LOAD group, implants exhibited occlusal contact at the heavy bite and light occlusal contact at the light bite. The relative occlusal forces were measured using T-scan at five different times, before implant crown delivery, after implant crown delivery, after function 1-2 months, 3-4 months, and 6-7 months. The periapical parallel x-rays were taken using a customized jig to analyze marginal bone loss before implant crown delivery, after implant crown delivery, and after function 6-7 months. The result showed no significant difference in the relative occlusal forces between the IPO and LOAD groups. The IPO group showed no significant difference in relative occlusal force between implant restoration and contralateral natural tooth after function 3-4 months. While in the LOAD group, the relative occlusal force between implant restoration and contralateral natural tooth after function 1-2 months was not significantly different. However, both groups showed that the relative occlusal force of implant restorations increased over time. Therefore, there was no significant difference between IPO and LOAD groups for marginal bone loss. The LOAD occlusion that lets the implant occlude faster seems convincing since the marginal bone loss did not show any significant differences. However, the finding was inconclusive on whether LOAD occlusion is better than IPO. A thorough follow-up study and increased sample size are needed.

Keywords: *implant occlusion, T-scan, occlusal force, relative occlusal force, bite force*

1. Introduction

Nowadays, dental implants have gained popularity for treating both partial and fully edentulous patients due to their high success rates. However, the success of implants depends on several factors. One of the keys to success is implant occlusion (Kim et al., 2005).

It is known that implants differ from natural teeth in many aspects (Kim et al., 2005). First, implants have no periodontal ligaments that act as shock absorbers and stress distributors. Consequently, they lack tactile sensitivity (Hämmerle et al., 1995). Moreover, since implants have osseointegration, making them act like ankylosis, the axial mobility of the implant is less than those in natural teeth (Schulte, 1995). In addition, the fulcrum of forces of the natural tooth is located at apical one-third of the root, whereas, in implants, it is at crestal bone (Schulte, 1995). Consequently, dental implants respond to occlusal force differently from natural teeth.

Trauma from occlusion occurs due to occlusal forces above the adaptive capacity of the attachment apparatus leading to periodontium injury (Hallmon & Harrel, 2004). In addition, lacking perception and reflex from periodontal ligaments lead those implants prone to overloading (Kim et al., 2005). Overloading is considered one of the causes of mechanical complications such as screw loosening or fracture, prosthesis

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fracture, or even implant itself fracture (Resnik, 2018). Moreover, overloading also plays an essential role in implant bone loss. Overloading causes marginal bone loss of implants by creating microfracture at the interface between bone and implant (Misch & Bidez, 1994; Miyata et al., 2000). So, to avoid those problems, the control and maintenance of implant occlusion are crucial (Resnik & Misch, 2018).

As mentioned, creating good occlusion plays an essential role in implant longevity. In 1994, Misch and Bidez (1994) proposed the implant-protected occlusion concept, which is modified from the natural tooth occlusion concept (Misch & Bidez, 1994). This concept aimed to reduce occlusal forces on implant prostheses to protect implants. Especially for occlusion of single implant prosthesis, the implant should have light contact at a heavy bite, while no contact at a light bite (Resnik, 2018). However, the implant occlusion concept was considered clinical empirical due to the lack of occlusal analysis tools and methods that have enough sensitivity and provide accurate and reliable data.

As we have known, the method that we generally use to perform occlusal analysis and adjustment is using articulating papers. It can easily identify occlusal contact areas and detect high spots or premature contacts. However, according to several studies, this method cannot illustrate occlusal loading accurately (Carey et al., 2007; Kerstein & Radke, 2014). Using articulating paper as an occlusal indicator has been considered a subjective method because it relies on the tactile sensation of dentists and patients. Moreover, this method cannot provide the other occlusion data, such as the relationship between occlusal force and time, the center of force, or the sequence of occlusal contact. So, many researchers have put much effort into developing a new occlusal analysis method for these reasons. Finally, in 1987, the Tekscan company introduced the occlusal analysis device using computer software to analyze, which is called T-scan (Nalini & Sinha, 2018). T-scan claimed to provide more accurate and reliable occlusal analysis than articulating papers (Kerstein, 2008). The occlusal force distributions of each tooth in the arches will be reported as the relative occlusal forces, which means the percentage of the force of that tooth compared with the rest. These relative forces will be shown in percentage. In addition, the center of forces at any time interval can be identified. Moreover, the relationship between time and occlusal force can be obtained (Sutter, 2019).

After that, some researchers started using the T-scan system to study implant occlusion. The results showed that even though the occlusion of implants is thoroughly adjusted at delivery, the occlusal loading of implants after function can be significantly changed over time (Luo et al., 2020). Moreover, some studies reported the negative effect of using implant-protected occlusion to adjacent teeth, especially in distal end situations (Rosen et al., 2016). Implant-protected occlusion makes the neighboring teeth receive much more occlusal loading. The results revealed that the adjacent teeth, such as premolars, had pathologies such as tooth mobility, fremitus, and widening PDL space (Rosen et al., 2017). Moreover, there was a possible association between implants and vertical root fracture in neighboring RCT teeth (Rosen et al., 2016). These problems might be generated from the method we use, using articulating paper, to create implant-protected occlusion is not sensitive enough to create optimum implant occlusion.

However, the clinical evidence of the implant occlusion is still scarcely reported. Few studies previously reported implant occlusion alteration after a function. Unfortunately, some of these studies provided only the data after the prostheses were connected and follow-ups, while others collected only before and after delivery. Furthermore, none of them have mentioned implant occlusion and bone loss of the implant.

2. Objectives

To analyze the relative occlusal forces of single posterior implant-supported fixed prostheses among IPO and LOAD occlusal contact designs over time using a T-scan system and to compare the marginal bone loss between those designs of single posterior implant-supported fixed prostheses over time

3. Materials and methods

3.1 Sample preparation

Twelve patients who required single posterior implant-supported prostheses at the Esthetic Restorative and Implant Dentistry, Faculty of Dentistry, Chulalongkorn University, were enrolled in this study. Patients were randomly divided into two groups which were implant-protected occlusion (IPO) and



LOAD group, as shown in Figure 1. The ethical committee of the Faculty of Dentistry, Chulalongkorn University, approved this study (HREC-DCU 2020-082).

3.2 Inclusion and exclusion criteria

For inclusion criteria, patients more than 20 years old who required single posterior implant-supported restorations were enrolled. The implants were placed with delayed placement protocol and occluded with natural teeth. Participants also had contralateral natural teeth, good periodontal health (no uncontrolled or active periodontitis), good medical and psychological health (no untreated or uncontrolled diseases), non-smoking and available for follow-up periods.

For exclusion criteria, patients were excluded if they presented with poor oral hygiene and periodontium (Uncontrolled or active periodontitis), TMD and joint problems, received other dental treatments that alter patient occlusion during the research period, had parafunctional habits or untreated/uncontrolled systemic diseases, received medications contradicted for implant treatments, and smoking.

3.3 Sample size

The sample size was calculated by means and standard deviations (two-tailed) of occlusal forces obtained from the study by Roque, Gallucci, and Lee, (2017)(Roque et al., 2017). The calculation was performed using the G*Power program version 3.1.9.6. with 0.05 alpha 0.8 power. The sample size was six subjects per group. Therefore, the total sample size in this study was twelve subjects.

3.4 Study procedures

The relative occlusal forces were collected using T-scan III (Tekscan Inc., USA) at five different times: before prostheses delivery, after prostheses delivery, and follow-ups after function 1-2, 3-4, and 6-7 months. It was noted that single implant prostheses of the IPO group delivered were checked to have no contact at light bite but have contact at heavy bite by using 12 μ m articulating papers (Arti-Fol 12 μ m, Dr. Jean Bausch GmbH & Co. KG, Germany). For the LOAD group, implant prostheses delivered were checked that they had contacted both at light bite (light contact) and heavy bite. Each patient was asked to sit in an upright position before performing the T-scan analysis. Then, the patients were instructed to bite at the same position on the sensors. After that, the T-scan analysis was performed. The sensor was placed between the central incisors of each patient and assured it coincided with the midline. The patients were asked to bite three times at MIP. The T-scan software processed the gathered data and demonstrated them into two-dimensional and three-dimensional images with different colors and bars. Color ranges from red, representing the high force, to blue, which means light force. For the bars, the higher one represents the higher force. The contact areas were reassured by using 65 μ m of articulating papers. For the controls, since all patients in this study had only one edentulous area, each implant would be compared with one control tooth on the contralateral side in the same arch.

For marginal bone loss analysis, periapical radiographs were also collected with relative occlusal forces using customized XCP but only after prostheses delivery and follow-ups after function 6-7 months. The customized XCP was made from acrylic resin (Duralay). The biteplate of XCP was added with Duralay. Then the patients were asked to bite down and hold it until it had an initial set. Then, let it set entirely outside the patient's mouth. This customized XCP was checked to whether it was seated in the same position before the radiographic examination and whether the two periapical radiographs we got were the same. This customized XCP was used every time the radiographic examination was performed (Nandal et al., 2014). All radiographic examinations were performed digitally using the PACS system. Before measuring bone loss, each radiograph was checked and calibrated by measuring the diameter and length of the implants in the x-ray compared with the actual dimension of those implants. Then, the bone loss was measured from the implant platform to the bone at the mesial and distal aspects at the crown on implant delivery visit (as a baseline) and after function 6-7 months. If the bone level were coronal to the platform, the number would be a positive value. If the bone level were apical to the platform, the number would be a negative value. Then, the differences in marginal bone loss between implant crown delivery and six months, both mesial and distal



aspects, were calculated. Only one person measured the marginal bone loss at a 2-week interval. A reliability test of X-ray interpretation was performed. The intraclass correlation coefficient (ICC) was 0.996, which was considered excellent reliability according to Koo and Mae Li's study (Koo & Li, 2016).

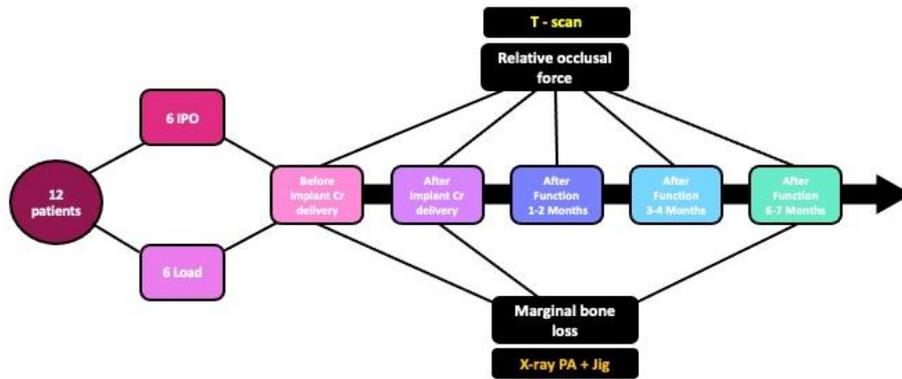


Figure 1 study protocol



Figure 2 T-scan system (the green occlusal sensor and command handle)

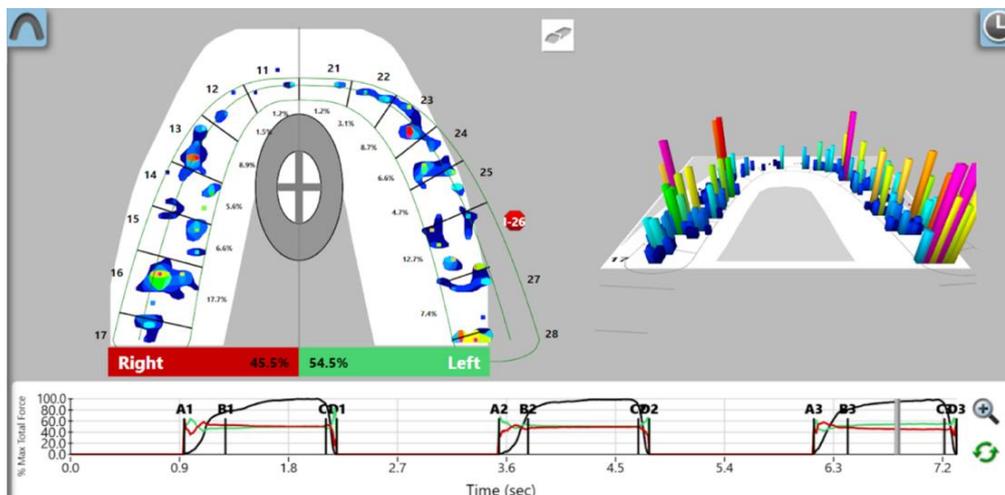
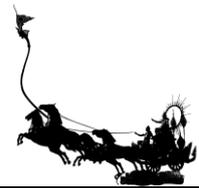


Figure 3 the results in 2D and 3D views



3.5 Statistical analysis

Three types of analysis would be performed in this study: cross-group, case-control, and within-group. All gathered data would be analyzed using IBM SPSS Statistics software (version 26 software SPSS Inc., Chicago, IL). The normality test would be performed first by the Shapiro-Wilk test. Since the relative occlusal force of implants at 1-2 months, 3-4 months, and 6-7 months were normally distributed, the differences in mean relative occlusal forces of implants and marginal bone loss between IPO and LOAD group (cross-group) would be analyzed by an independent t-test. While the rest were analyzed by the Mann-Whitney U test to compare means between groups. For case-control analysis, paired t-test would be used to analyze the differences in mean relative occlusal forces between control teeth and implant prostheses because they had a normal distribution. Finally, the differences in mean relative occlusal forces of implants in each group at different times (within-group) were analyzed by the repeated measure ANOVA since they were normally distributed. The results would be statistically significant if the p-value was less than 0.05 as shown in Figure 4.

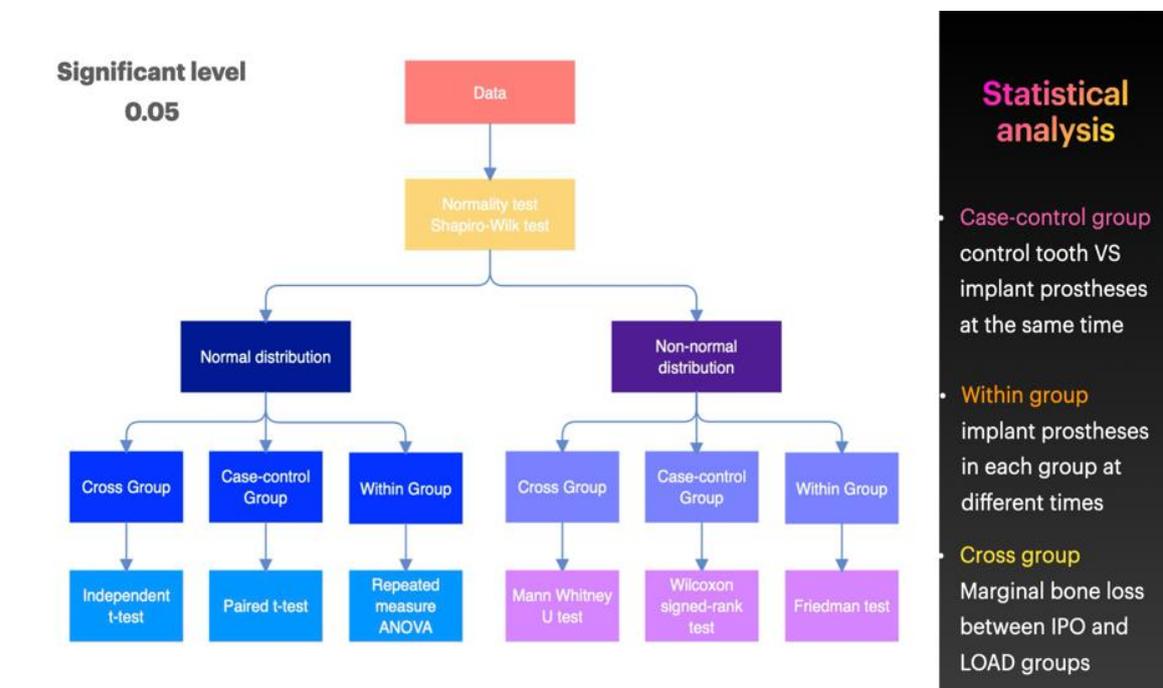


Figure 4 statistical analysis

4. Results and Discussion

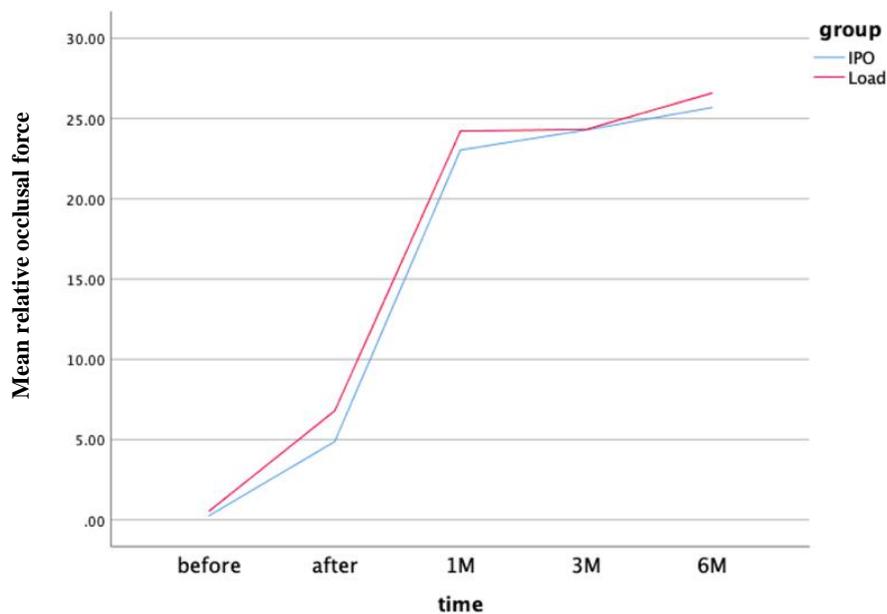
4.1 Results

Twelve participants were randomly divided into two groups. Each group contained two men and four women. The mean age of patients was 35 years old. Ten out of twelve edentulous areas are the first molar. And the rest are the second premolars. This study included twelve implants from 4 different systems, which were Straumann, Nobel, Neodent, and Dentium, as shown in table 1.

**Table 1** Basic characteristics

Data	IPO	LOAD	Total	p-value
Age, Mean (SD)	33.17 (11.44)	38.67 (13.52)	35.92 (12.28)	0.47
Gender, N (%)				
Female	2 (33.3)	2 (33.3)	4 (33.3)	1.00
Male	4 (66.7)	4 (66.7)	8 (66.7)	
Brand, N (%)				
Dentium	4 (66.6)	2 (33.3)	6 (50)	0.45
Straumann	1 (16.7)	1 (16.7)	2 (16.7)	
Nobel	1 (16.7)	1 (16.7)	2 (16.7)	
Neodent	-	2 (33.3)	2 (16.6)	

The repeated measure ANOVA was performed to analyze the differences in mean relative occlusal forces of implants in each group at different times. Overall, the relative occlusal forces of implants in both groups increased over time, as shown in Figure 5. The mean relative occlusal forces for the IPO and LOAD groups were 3.97 ± 0.91 and 6.67 ± 3.67 at implant crown delivery visit, respectively. Comparing these two groups showed that the relative occlusal forces between IPO and LOAD groups were not significantly different at any time. In addition, both groups showed that the relative occlusal forces of implant restorations were increased during the follow-up period. The relative occlusal forces between implant restorations and control tooth for the IPO group started not to show significant differences after 3-month in function when comparing implant restoration site and natural control tooth. In contrast, significant differences were not found in the LOAD group after a 1-month follow-up, as shown in Table 2.

**Figure 5** The relative occlusal forces of implants of both groups increased during the follow-up period

**Table 2** Results of the relative occlusal forces

Parameter	Mean (SD) of a relative occlusal force of implant (%)		p-value ^{a,b}	Mean (SD) of a relative occlusal force of Control (%)		p-value ^c	
	IPO	LOAD		IPO	LOAD		
	Before	0.00 (0.00)	0.80 (0.80)	0.30 ^b	15.12 (5.65)	0.00	12.97 (4.06)
After	3.97 (0.91)	6.67 (3.67)	0.83 ^b	15.68 (2.95)	0.00	9.67 (4.25)	0.02
1-2 M	6.10 (3.37)	9.03 (4.81)	0.17 ^a	10.35 (7.11)	0.01	15.3 (6.02)	0.05
3-4 M	9.10 (4.88)	9.87 (3.76)	0.54 ^a	12.63 (6.30)	0.24	12.10 (4.62)	0.26
6-7 M	12.23 (8.11)	14.37 (7.50)	0.99 ^a	17.05 (1.43)	0.08	11.03 (6.31)	0.60

a Difference between IPO and LOAD groups was analyzed using an independent t-test.

b Difference between IPO and LOAD groups was analyzed using the Mann-Whitney U test.

c Difference between implant and control groups was analyzed using paired t-test.

For marginal bone loss, the marginal bone loss of the IPO group at implant at the crown delivery visit were 1.37 and 1.33 at mesial and distal, respectively. In comparison, the marginal bone losses of the LOAD group at the crown delivery visit were 1.37 and 1.50 at mesial and distal, respectively. After six months in function, the marginal bone loss between both groups was not significantly different, as shown in Table 3.

Table 3 Results of marginal bone loss

Marginal bone loss (mm)	Mean (SD) (mm)		p-value
	IPO	LOAD	
DeltaBefore – 6M M ^a	0.12 (0.23)	0.02 (0.19)	0.44
DeltaBefore – 6M D ^b	0.20 (0.19)	0.30 (0.18)	0.63

a Mean Difference of marginal bone loss between implant crown delivery and 6 months (Mesial)

b Mean Difference of marginal bone loss between implant crown delivery and 6 months (Distal)

4.2 Discussion

The way that we usually use to check occlusal contact in dentistry nowadays is using articulating papers. Even though this method is easy to use and cost-effective, it is also considered a subjective method since it relies on dentist forces and experiences. Furthermore, using articulating papers for adjusting occlusion seems unsuitable, especially for implant occlusion, since several studies stated that it did not provide precise and accurate data (Carey et al., 2007; Kerstein & Radke, 2014). Moreover, in terms of sensitivity, using articulating paper has insufficient sensitivity since it can only check one pair of occluded teeth at a time. Therefore, the computer-assisted device for checking occlusion is favorable (Kerstein, 2008). Compared with the conventional method, T-scan can check the occlusion of all teeth in one bite. Besides, it can also check the occluded teeth order whether which tooth has contact first. Therefore, this device seems suitable for implant occlusion adjustment (Ayuso-Montero et al., 2020; Koos et al., 2010; Nalini & Sinha, 2018).

For implant occlusion, the occlusion is usually designed using the IPO concept, which means that implant restoration has a contact at the heavy bite and no contact at light bite (Misch & Bidez, 1994; Resnik, 2018). The main idea of this concept is good because natural teeth will protect the implant restorations. However, having this occlusion by using articulating papers might not be appropriate for implant restoration since the occlusal forces tend to be loaded on adjacent natural teeth, leading to pathologies such as root fracture, mobility, and traumatized tooth (Rosen et al., 2016; Rosen et al., 2017). This circumstance became worse in distal end restoration, as several studies reported (Rosen et al., 2016; Rosen et al., 2017). All of these might be because the method we use to check occlusion has not had enough sensitivity, as mentioned. Creating implant-protected occlusion using articulating paper to check not to hold in light bite seems under



occlusion and a bit slower than it should be. The results from several papers showed that even though the occlusion of implants was carefully adjusted at the crown on implant delivery visit, the occlusal loading of implants after function could be significantly changed over time (Luo et al., 2020; Roque et al., 2017). The occlusions of those implant prostheses created according to the IPO concept were diminished due to the continued eruption of opposing teeth (Luo et al., 2020; Roque et al., 2017). The antagonist would continually erupt until they contact later. This gap time would create more chance for adjacent teeth to receive a higher load, leading to the problems mentioned earlier.

With all mentioned above, to find the optimum implant occlusion, this study experimented with another implant occlusion design as LOAD implant occlusion, in which implant restorations contacted at heavy bite as IPO one and contacted at light bite (but slightly hold Arti-Fol). However, this type of occlusion still followed the IPO concept but would let the implant restorations contact a bit faster using a T-scan device. The results showed no significant differences between the relative forces of the IPO and the LOAD group. Furthermore, when focusing on each group, the relative occlusal forces between implant restoration and control natural tooth of the IPO group showed no significant differences after three months in function. In contrast, the relative occlusal forces between implant restoration and control natural tooth of the LOAD group showed no significant differences after a one-month follow-up. These were probably due to the continuing eruption of the opposing teeth and lacking PDL in the implant, as reported by several authors (Luo et al., 2020; Roque et al., 2017). Another interesting point is that from Figure 5, the rapid changes of relative occlusal forces were found after one-month function in both groups. These changes may be because the patient tried to use the implant and that side for function after receiving implant prostheses—so patient adaptation and getting familiar with the implant prostheses might play an important role here. However, the passive eruption can also cause this situation. Nevertheless, to prove, the superimposition of radiographs such as CBCT might confirm this phenomenon which can be designed in further study.

Another parameter that was analyzed in this study was a marginal bone loss since one of the implant success criteria is a lack of radiographic radiolucency around the implant and bone loss of no more than 2 mm annually (Nandal et al., 2014). Besides, Miyata et al. tested occlusal overloading on implants in an animal study and found that overloading is associated with crestal bone loss of the implants (Miyata et al., 2000). Therefore, marginal bone loss might be a good indicator of whether this designed implant occlusion is good. The measurements in this study were performed at the MIP position to ensure that the implants were not overloaded since microfracture at crestal bone leads to crestal bone loss caused by overloading the implant at MIP. So, if the LOAD design revealed more marginal bone loss than the conventional IPO design, it would mean that the LOAD design might not be the optimum implant occlusion we seek. The marginal bone loss was measured at the mesial and distal sides of implant restorations. The implants in this study were placed subcrestally, so the marginal bone loss was positive in both groups. However, the result showed no significant difference in marginal bone loss between IPO and LOAD groups. Consequently, the LOAD-designed occlusion might potentially be the optimum implant occlusion.

However, this study contained several limitations. First, this study was done during the COVID-19 pandemic. Therefore, finding participants and appointing follow-ups were challenging to perform and completed as the study procedure was planned first. Moreover, the sample size was relatively small, and the follow-up period was quite short. Therefore, it needed to be done with a larger number of participants and a longer follow-up period for a clearer conclusion.

5. Conclusions

From this study, the relative occlusal forces of implants increased during the follow-up period, especially between after implant crown delivery and the first month in function. Therefore, it is recommended to recall patients periodically, especially one month after implant crown delivery.

In addition, designing implant occlusion as LOAD group, which was implant restorations with occlusal contact at both light, and heavy bite (but light contact), seemed to have the potential to be the optimum occlusion for implant since the marginal bone loss between both groups did not show any significant



differences. This implant occlusion design might help adjacent teeth to share occlusal loading better. However, further study with larger sample size and longer observation time is needed.

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