The Relative Occlusal Force of Distal End Implant and Adjacent Tooth: a Cross-Sectional Study

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Abstract

The complication of the natural tooth adjacent to the distal end implant has frequently been reported. The vertical root fracture occurred in heavily restored teeth near the implant, especially in Kennedy's Class I and Class II edentulous area. Previous studies suggested that the occlusion design of the implant may cause overload in the adjacent tooth. This cross-sectional study aimed to compare the relative occlusal force between the implant in the distal end and the tooth adjacent to the implant in maximum intercuspation. Patients with implant restoration replacing teeth in free end space adjacent to natural tooth were recalled. The occlusion is examined as a shim stock passes through the occluded tooth in heavy or light bites. The heavy bite or a light bite with shim stock that cannot pull through is HB1 or LB1. If the shim stock can pull through it is considered HB0 or LB0. The implant is classified into 3 groups, HB1LB0, HB1LB1, and HB0LB0. The T-scan was used to determine the relative occlusal force of the implant and adjacent tooth in each group. A total of 20 patients with 45 implants were recalled and examined. The mean duration of the overall functional implant is 3.35 years. The occlusion type of implant with HB1LB1 is 4.44%, HB1LB0 77.77%, and HB0LB0 17.77%. There was a significant different between relative occlusal force of HB0LB0 implant group (M = 1.94, SD = 2.36) and adjacent teeth (M = 11.64, SD = 7.54); $p = 0.025$. The relative occlusal force of the distal end implant and the adjacent mesial tooth was a statistically significant difference in maximum intercuspation of the HB0LB0 group. Further prospective control or randomized control study should be conducted to find the cause-relationship between the occlusion of the implant distal end and failure of the adjacent tooth to prevent harming both the implant and the adjacent natural tooth.

Keywords: *Relative Occlusal Force, Distal End Implant, Adjacent Tooth, Implant Protected Occlusion*

1. Introduction

The dental implant has been used to restore missing teeth for many decades; the ability to bear loading on a dental implant is one of the critical successes in restoring a tooth. However, the implant has some biological limitations that may limit the force. At current knowledge, the occlusal design on how occlusal force is loaded on the implant is based on animal studies and expert opinion. (Goldstein, Goodacre, & Taylor, 2021; Gotfredsen, Berglundh, & Lindhe, 2001a, 2001b, 2002; Heitz-Mayfield et al., 2004; Isidor, 1996, 1997; Kozlovsky et al., 2007; Miyata et al., 1998; Miyata et al., 2000, 2002) The occlusal design concept is based on the different movements between the implant and natural tooth (Parfitt, 1960). The periodontal ligament in a natural tooth exhibits a movement when loaded by occlusal force, but the implant does not have a periodontal ligament. This lack of movement and shock absorber make the implant vulnerable and prone to premature contact. (Misch & Bidez, 1995). Moreover, the sensory receptor in the periodontal ligament enhances the ability to bear loading. It prevents the natural tooth from overloading in contrast to the osteointegration implant, which has lower osseoperception from alveolar bone (Hammerle et al., 1995). For these reasons, the implant-protected occlusion concept is mandatory for occlusion in implants (Goldstein et al., 2021; Kim et al., 2005).

The implant-protected occlusion concept prevents the occlusal overload in the implant by having the implant slightly under occlusion than the natural tooth (Misch & Bidez, 1994). Most of the time, it is accomplished by having the patient bite as a reference. The patient is asked to bite in light and heavy bites.

Then, the shim stock is used to adjust the occlusion. The implant is usually not in contact with light bites but contact with heavy bites using the shim stock as a reference. In an implant with an adjacent tooth mesial and distal, the natural tooth shares the load while the implant is not in contact. However, in the distal end, the tooth mesial to implant bear a load of occlusion before the implant is in contact. Many studies reported a vertical root fracture in tooth distal ended to the implant, particularly in premolar with root canal treatment (Lee et al., 2016; Rosen et al., 2016; Rosen et al., 2020; Terauchi et al., 2015). Eye Rosen also suggested that having implant lighter contact in the distal end may cause overloading on the adjacent tooth near the implant (Lee et al., 2016; Rosen et al., 2016).

When using the articulating paper as a marker for adjusting the restoration. The occlusal force cannot be measured because the articulating color mark size did not show force measurement (Carey et al., 2007; Kerstein & Radke, 2014). The method used is subjective to the patient bite and the dentist's clinical experience, which makes it challenging for the dentist to adjust the optimum occlusal height for implant restoration.

One method used to evaluate the occlusal force as digital numbers are the T-scan system (T-Scan III, Software version 8.0.1, Tekscan, Inc., Boston, MA, USA). This method used the resistance in voltage and translated to the percentage in each bite/timing. When upper and lower teeth occlude, the resistance in pressure is recorded as resistance voltage and translated into data described as relative occlusal force (Kim, 2020). Each tooth has a different relative occlusal force, each timing depending on the bite force. This method benefits the measurement of bite force during implant function and can be evaluated compared to the adjacent tooth. There is no research comparing the relative occlusal force in distal end implants and adjacent teeth to the author's knowledge. To compare the force on implants and adjacent mesial teeth, this evaluates the difference between the relative occlusal force of distal ended implants and the tooth mesial adjacent to implants. The null hypothesis was there was no difference in the relative occlusal force of a distal end implant and an adjacent mesial natural tooth.

2. Objectives

To compare the relative occlusal force between the implant in the distal end and the adjacent tooth mesial to the implant biting in the maximum intercuspation.

3. Materials and Methods

This cross-sectional study observed the relative occlusal force of the implant placed in the distal end (Kennedy's Class I and Class II edentulous area) and adjacent tooth mesial to the dental implant using a T-scan occlusal analyzer system (T-Scan III, Software version 8.0.1, Tekscan, Inc., Boston, MA, USA). The study population was 20 patients treated with implant support fixed prostheses at the Esthetics restorative and Implant clinic, Chulalongkorn University. The duration of implant function was from 1 January 2010 – to 1 January 2020. The population size was calculated using the N4studies program and the study of "Association between dental implants in the posterior region and traumatic occlusion in the adjacent premolars: a long-term follow-up clinical and radiographic analysis" was used as a reference (Lee et al., 2016). The output of the sample size calculation from n4Studies: For estimating the infinite population proportion, Proportion (p) = 0.067, Error (d) = 0.15 Alpha (α) = 0.05, Z (0.975) = 1.959964 Sample size (n) = 11. Another 9 samples were added for dropout patients. The reliability of the T-scan was analyzed using the interclass correlation coefficient (ICC).

Inclusion criteria:

Patient with implant restoration replacing molars in distal end space with existing opposing tooth (natural tooth with or without fixed prosthesis) contact in function for at least one year.

Chart recording

The occlusal contact was recorded using 8-micron shim stock in light-bite (LB) and heavy-bite (HB). The purpose of recording the occlusal contact using shim stock was to evaluate the clinical occlusion of the implant and adjacent teeth. The shim stock was recorded as LB1(Light bite- shim stock cannot pull through when biting), LB0 (Light bite- shim stock pull thought when biting), HB1 (Heavy bite- shim stock cannot pull thought when biting), and HB0 (Heavy bite- shim stock pull thought when biting).

The relative occlusal force was recorded using T-scan (T-Scan III, Software version 8.0.1, Tekscan, Inc., Boston, MA, USA). The patient was asked to bite in maximum intercuspation by clenching three times, and the recording was made when the patient was sitting upright in the dental unit. Two selected patients were asked to record the T-scan three times, and the relative occlusal force record was compared for the reliability test.

T-scan

The photograph of each arch was taken in articulating color on the occlusal view. The alginate impression is taken, and the model stone is created. Each tooth has measured the width from the mesial-distal marginal ridge and inputs the width to the T-scan software. The mean relative occlusal force of the implant was compared with the relative occlusal force of the adjacent tooth. All the information was collected in the spreadsheet for analysis.

Data analysis

The relative occlusal force of the implant in the distal end and tooth adjacent to the implant were compared using a paired-samples t-test.

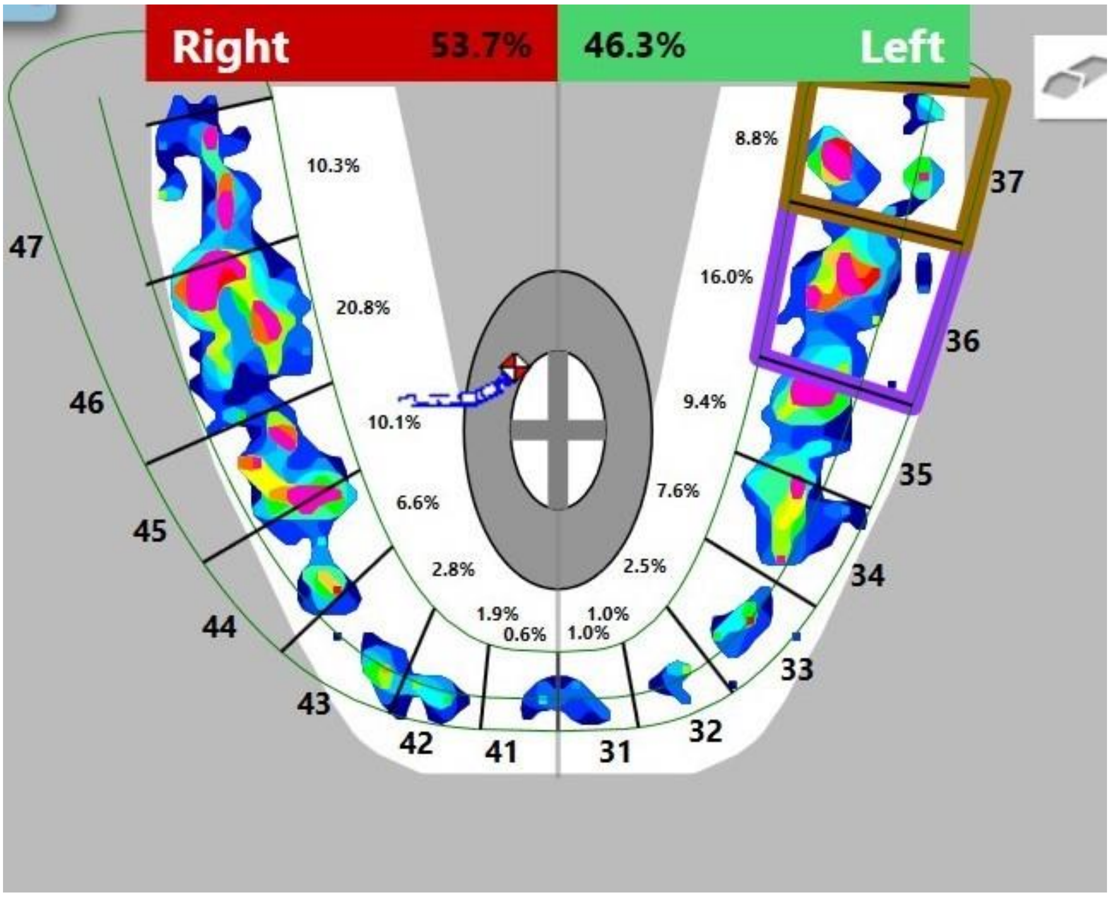

Figure 1 The example of relative occlusal force on distal free end implant at #36 #37 and the adjacent tooth at #35

Figure 2 The photograph was taken to verify the occlusion mark with articulating paper

4. Results and Discussion

Results

The ICC with agreement definition and 95 % confidence interval is 0.825 (0.675-0.906) (Koo & Li, 2016). Twenty patients with 45 implants placed in Kennedy's Class I or Class II edentulous area were recalled and examed. Baseline characteristics of patients and implants was shown in Table 1. The mean functional of implants was 3.35 years. The occlusion type of implant with HB1LB1 is 4.44%, HB1LB0 77.77%, and HB0LB0 17.77%. The relative occlusal force of the implants and the adjacent tooth was shown in table 2. The Occlusion type was listed as HB1LB0, HB1LB1, and HB0LB0. The example of the relative occlusal force of implant and adjacent tooth in maximum intercuspation was shown in Fig 1. From Wilcoxon Signed Ranks test, there was a statistically significant difference between relative occlusal force of HB0LB0 implant group (M = 1.94, SD = 2.36) and adjacent teeth (M = 11.64, SD = 7.54); $p = 0.025$. There was no statistically significant difference between relative occlusal force of HB0LB1 implant group (M = 9.27, SD = 7.58) and adjacent teeth (M = 10.05, SD = 5.71); $p = 0.758$. From Paired Sample Test, there was no statistically significant difference between relative occlusal force of HB1LB1 implant group (M = 16.85, SD = 3.32) and adjacent teeth (M = 3.2, SD = 0); $p = 0.109$.

Table 1 Baseline characteristics of the patients and implants in this study

Characteristics		Numbers	Percentage
Patients		20	100
Gender			
	Male	5	25.00
	Female	15	75.00
Implants		45	100.00
Position			
	Maxilla	7	15.55
	Mandible	38	84.44
Duration of function Means = 3.35 years.			
	1-3 years	24	53.33
	4-6 years	20	44.44
	7-9 years	1	2.22
Occlusion type			
	HB1LB1	2	4.44
	HB1LB0	35	77.78
	HB0LB0	8	17.78

Table2: The ROF of implants and adjacent teeth

Patient	Implant	Occlusion type	Adjacent tooth ROF	Implant ROF
P1	45	HB1LB0	15.20%	1.67%
	46	HB1LB0		0.60%
	47	HB1LB0		0.70%
P2	46	HB1LB0	11.40%	50.00%
	47	HB1LB0		11.30%
P3	34	HB1LB0	4.40%	4.90%
	35	HB1LB0		2.20%
	36	HB1LB0		4.00%
	37	HB1LB0		2.00%
P4	46	HB1LB0	9.20%	30.65%
	47	HB0LB0*		0.40%
P5	36	HB1LB0	2.60%	11.50%
	37	HB1LB0		28.00%
P6	36	HB1LB0	14.40%	1.20%
	37	HB0LB0*		0.00%
P7	36	HB1LB0	7.40%	6.20%
	37	HB1LB0		3.00%
P8	46	HB1LB0	4.00%	7.80%
P9	16	HB0LB0*	20.50%	0.20%
	17	HB0LB0*		1.80%
P10	34	HB1LB0	21.40%	11.20%
	35	HB1LB0		5.20%
	36	HB1LB0		6.00%
	37	HB1LB0		0.80%
P11	46	HB1LB1	3.20%	14.50%
	47	HB1LB1		19.20%
P12	36	HB1LB0	8.50%	4.70%
	37	HB1LB0		14.40%
P13	36	HB1LB0	5.90%	11.70%
	37	HB1LB0		12.80%
	38	HB1LB0		23.00%
P14	46	HB0LB0*	16.30%	7.40%
	47	HB1LB0		11.30%
P15	47	HB1LB0	19.60%	6.60%
P16	26	HB0LB0*	9.00%	2.00%
	27	HB1LB0		11.50%
P17	35	HB0LB0*	2.20%	1.60%
	36	HB1LB0		15.80%
	37	HB1LB0		17.00%
P18	25	HB1LB0	10.00%	7.80%
	26	HB1LB0		9.40%
	27	HB1LB0		15.50%
P19	36	HB1LB0	9.40%	16.00%
	37	HB1LB0		8.80%
P20	47	HB0LB0*	1.00%	2.10%

ROF: relative occlusal force
*: Statistically difference

Discussion

This cross-sectional study aimed to clarify the occlusal force on the tooth adjacent to the implant and implant in the distal end. The occlusion loading measurement selected in this study was the T-scan system, which provides the relative force occlusal force value. This computer-assisted dental occlusion analyzer method has the benefit of recording the percentage of force in each tooth subjectively and has been widely used in dental occlusion analysis research. However, the mapping of force depends on the width input of the tooth. Even though the software has mean widths of each tooth. Each patient's tooth width, including the spacing area, was inserted into the software for accuracy when determining the relative occlusal force. In addition, the photograph was taken with articulator color on the tooth surface to compare the mark of occlusion in the tooth and software. Due to the difference in bite force of the patients when biting, the patient was asked to bite in maximum intercuspation 3 times to evaluate the proper bite in software. When biting the T-scan, the patient is set in an upright position to create the normal occlusion function.

In this research, the relative occlusal force of implants and adjacent mesial teeth in maximum intercuspation were not significantly different in HB1LB0 and HB1LB1 groups ($p < 0.05$), which might be because, in the maximum intercuspation, the force was spread evenly between teeth and implants in most patients. In this situation, maximum intercuspation force was considered a heavy bite when checking with shim stock, which usually catches the shim stock as the natural tooth occluded implant restoration. In addition, the pressure on the implant might change during the function period. The implant's force gradually increases after function over the years. According to research using T-scan, which measures the force on implant prospectively after loading in the final restoration. The force increases significantly in the first three months and continued to increase over three years of follow-up. (Madani et al., 2017; Qiang et al., 2020). This may be because the opposing tooth to the implant is continued to erupt over the year of function while the implant has no movement. The passive eruption of the tooth to meet the occlusal stop happens with the enamel wear in function depending on the type of food and the type of restoration occluding with the tooth. Normal function enamel wears at 35.1 ± 2.6 µm per year for molar teeth (Kailas et al., 2015). The eruption could compensate for wear rate and small underloading implant to some extent. Some implants did not follow the implant-protected occlusion (HB0LB0) scheme. In this group, the relative occlusal force was significantly different between the adjacent tooth and distal end implant, which might be due to over adjusting of occlusion when using the shim stock and articulating paper. Whereas the final restoration of the implant is usually highly polished and difficult to adjust or identify the occluded point. The patient's bite is sometimes different when asked to occlude in light or heavy bite. The gap between the occlusion is too far for the tooth to erupt into the contact position, which might cause overloading in the tooth adjacent to the implant because the load is concentrated on the tooth mesial to the implant (Lee et al., 2016). However, if the implant is loaded heavily or occluded before the tooth in the HB1LB1 group, this might overload the implant occlusion and cause bone loss.

When the implants were replacing both molars and premolars such as in patients P3 and P10 the occlusion on the implant is usually harder to adjust because anterior teeth should not be loaded with heavy occlusion. The relative occlusal force in a heavy bite should be distributed throughout the arch. In this situation, the dentist should carefully check the occlusion not only in the implant but also in the natural tooth to make sure that there is no overloading occlusion.

The implant that replaces the molar in posterior teeth should be loaded with mastication force using the implant-protected occlusion scheme (Kim et al., 2005). The method of checking occlusal force is by using articulating paper and shim stock to match the height of occlusal contact to the opposite occlude tooth. However, this method has some concerns regarding subjective interpretation and lack of masticatory force measurement or timing of occlusion. In contrast, the occlusion checking with the digital method provides a more accountable measurable force that can be interpreted, which can benefit the occlusion of both implant and adjacent tooth, especially in the distal end area. Since we are entering the digital era in dentistry, the benefit of digital scanners and computer-assisted dental occlusion analyzer methods can increase the accuracy of occlusal adjustment in implant dentistry.

The limitation of this study is that the relative occlusal of tooth and implant in maximum intercuspation did not reproduce the function of the masticatory system. The time/force graph can be used in further study to evaluate the completed cycle of function and habitual contact. Even though this study measures the tooth's width and inserts a parameter into the software. Using the digital scanner to impose the 3D file might have more accuracy in force mapping. Finally, a randomized control or prospective control study with a larger sample size is needed to clarify the cause-relationship between distal end implant occlusion and adjacent tooth complication.

5. Conclusion

In conclusion, the relative occlusal force of implant in the distal end area and adjacent mesial tooth are statistically significant differences in maximum intercuspation in the HB0LB0 group. There was no difference in relative occlusal force between the HB1LB1 and HB1LB0 groups. More detail of force and occlusion time should be studied for more accurate occlusion data in distal end implant and adjacent teeth. A prospective control study or randomized control study should be conducted to identify the causal relationship of occlusal overload on both implant and adjacent tooth

6. Acknowledgments

The author would like to thank Asst. Dr. Prof. Soranun Chantarangsu for good recommendation and help regarding the statical analysis.

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