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Influence of immediate loading on provisional restoration in dental implant stability

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Abstract. The success of dental implant treatment is determined by the primary stability at placement. One factor that could influence this stability is occlusal loading through provisional restoration. Two types of loading protocols are usually used: immediate and delayed loading. However, some controversies remain about the influence of occlusal loading on implant stability. Therefore, the influence of immediate loading on implant stability must be studied. An animal study was conducted by placing nine dental implants in the mandibular jaw of three *Macaca fascicularis*. Provisional restorations with various occlusal contacts (no, light, and normal contact) were placed on the implant. The implant stability was measured using the Ostell ISQ three times: immediately (baseline) and at the first and second months after implant placement. The implant stability between implants with no and normal occlusal contact as well as light and normal occlusal contact showed significant differences ($p < 0.05$) at the first and second months after implant placement. However, no significant increase ($p > 0.05$) in implant stability was seen at the baseline and the first and second months after implant placement for all occlusal contact groups. Immediate loading influenced the implant stability, and provisional restoration of implant without occlusal contact showed the highest implant stability.

1. Introduction

Nowadays, dental implant treatment is one of the alternative rehabilitation treatments for tooth loss. In this treatment, an implant supporting a crown is embedded in the bone. Successful implant treatment results in an aesthetic, functional, and comfortable restoration. The other advantages of dental implants are that they are not invasive to the remaining teeth and they stimulate the bone to prevent resorption [1]. The success of dental implant treatment is assessed by osseointegration. Osseointegration depends on the primary stability. Osseointegration is the healing process that occurs after implant fixation to the bone, with the formation of a direct structural relationship between the bone and the implant. This structural relationship is microscopically demonstrated by the absence of connective tissue between the bone and the implant [2-3].

The success of osseointegration can be evaluated using several methods, including percussion, radiography, and Resonance Frequency Analysis (RFA) [4]. By using the RFA method, implant stability can be determined using the Implant Stability Quotient (ISQ) value. ISQ ranges from 1 to 100, and it indicates the rigidity of the bond between the bone and the implant. A higher ISQ value indicates better implant stability [5]. If the implant stability is good, bone remodeling may occur around the implant, thus promoting osseointegration. The success of osseointegration is indirectly demonstrated by the stability, namely, the lack of implant mobility. Therefore, regular control and

maintenance of implant stability are necessary to realize successful treatment [6]. One of the factors that can disrupt the implant stability is excessive force on the implant.

Load can be applied on an implant supporting a denture in two ways: immediate and delayed loading. Immediate loading can be applied by installing a provisional crown immediately after implant placement. Provisional restoration is used for a short period to promote soft tissue healing; therefore, the implant treatment results in improved aesthetics. In addition, provisional restoration can also increase the patient's confidence because the missing tooth is replaced, so the patient is not seen with missing teeth [7-8]. However, other studies have stated that a short period of healing before applying an immediate load on the implant may increase the risk of implant failure [9]. Furthermore, previous study [10,11] reported that the treatment success with immediate loading is no different from that with delayed loading.

Implant failure may be caused by the load received by the implant through occlusion [12]. Under immediate loading, provisional restoration can have contact or no contact with the opposing tooth. If the provisional restoration makes contact with the opposing teeth, there is an increased risk of implant failure. However, some controversy remains the restoration of occlusal contacts supported by implants. Excessive occlusal loading on the implant can cause failure of osseointegration, in turn resulting in failure of implant treatment. Therefore, occlusal contacts that are distant from the antagonist can reduce the risk of implant treatment failure [9]. Similarly, Nedir *et al*. [13] stated that in an implant with immediate loading, the restoration should be made free of contact so that osseointegration can be successful. In contrast, Lopez [14] stated that the occlusal contact should be minimized in the restoration supported by implants in both immediate and delayed loading. Dewi [15] found that osseointegration can be achieved in provisional restorations with immediate loading with light occlusal contact with the opposing tooth. Few studies have focused on the intervention of variation in the restoration's occlusal contact post-implant with both immediate and delayed loading. This study was conducted to determine the effects of occlusal contact on the stability of an implant subjected to immediate loading. This study uses *Macaca fascicularis* due to the similarity of its anatomical tooth structure and jaw bone to that of humans [16]. The implant stability is measured using the RFA method based on the intervention of occlusal contact without contact and with light contact and normal contact.

2. Materials and Methods

2.1 Initial Research Preparations

This study was conducted using three *M. fascicularis* aged 6 years and weighing 3.5–4 kg with good overall health and no systemic diseases. The animals were quarantined for 6 weeks to protect them from systemic diseases and to optimize their health status. Custom trays were made using a Shellac baseplate on a study model from previous studies. The study model is a model of the jaws of *M. fascicularis*. Before an impression is made, the custom trays are adapted to the animal's jaw. An impression of both the upper and the lower jaws is made using the custom tray and alginate.

2.2 Tooth extraction

Teeth 42, 44, 46, 32, 34, 36, and 38 on the lower jaw were extracted. Observations are made 2–3 times a day on days 2–7 depending on the condition of the animal. Observations are recorded in the observation sheet to assess pain by referring to a pain scoring guide.

2.3 Making provisional restoration

Anatomical models before tooth extraction were duplicated using stone gips and were mounted on an articulator. Teeth 46 and 36 in the articulated model that have been extracted are reduced to the extent of the cervical are and followed by performing a provisional restoration using heat-cured acrylic resin, following the actual shape and size of the animal's teeth. Then, the restorations are placed and their occlusion against the opposing teeth is adjusted (Figure 1).

2.4 Implant placement

Implants are placed on the experimental animal's jaw two months after tooth extraction on teeth 46, 46, and 38 (Figure 2). Before the procedure, the subjects are sedated using ketamine (15 mg/kg). Around 5 min after the sedatives have acted, the subjects are intravenously given general anesthesia with a 1.8 ml Propofol bolus (4 mg/kg). The first step was to determine the location of the implants using an explorer; the implants are placed using the flapless method.

2.5 Placement of provisional restoration and examination of occlusal contact

Once the implant has been placed, temporary restorations are placed by the following procedure: (1) placement of provisional restoration on the same day with implant placement on tooth 36 with light contact. Light contact is determined using a 60-µm-thick articulating paper; when the lower and upper jaws make contact, a point or dot will be marked on the restoration; (2) placement of provisional restoration on tooth 46 with normal contact. Normal contact is determined using a 20-µm-thick articulating paper; when the upper and lower jaws make contact, an area will be marked on the restoration.

2.6 Examination of implant stability

The implant stability is examined using Ostell ISQ (Fig. 3) on the same day as implant placement after 1 and 2 months. Teeth 46, 36, and 38 are examined. Before the dental implant stability is examined using Ostell ISQ, magnets are placed on the buccal and lingual side of the provisional restoration as a transducer, and a probe is directed toward the magnet in a buccolingual direction at 2–3 mm distance. When the probe is at the right distance, the instrument will generate a short beep. A longer beep indicates that the examination has been completed, and the ISQ value can be seen on the display screen of the instrument.]

Figure 1. Working model with provisional restoration mounted on an articulator

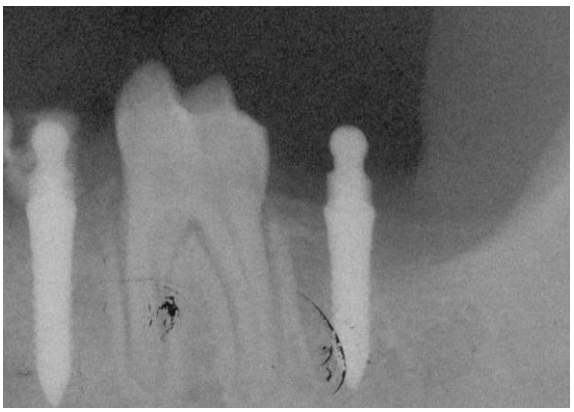

Figure 2. Implants placed teeth 36 and 38

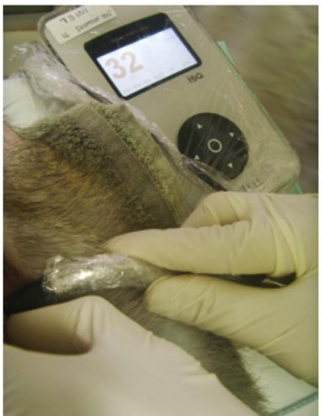

Figure 3. Examining implant stability

3. Results and Discussion

3.1 Results

In this study, nine implants are placed using the immediate loading method on three *M. fascicularis*. Each *M. fascicularis* is mounted with three implants with normal and light occlusal contacts and no contact. Then, the implant stability is measured using the RFA method (Ostell ISQ) immediately after it is placed (baseline) and after 1 and 2 months. All data is collected and processed using SPSS v.20. Table 1 shows the mean implant stability values obtained using the immediate loading method with no occlusal contact, light contact, and normal contact at baseline and the first and second months.

Table 1. Implant stability values obtained using immediate loading method with no occlusal contact, light contact, and normal contact at baseline and the first and second months

Contact	ISQ value								
	Baseline			First month			Second month		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
No contact	66	66	0	69	69	0	70.66	71	0.57
Light contact	66	66	0	68.66	69	0.57	70.33	70	0.57
Normal contact	66	66	0	66.33	66	0.57	67.33	67	0.57

The mean implant stability value under immediate loading immediately after implant placement without occlusal contact and with light and normal occlusal contact is 66. Meanwhile, at 1 month after implantation, the corresponding values are 68.66, 66.33, and 69. At 2 months after implementation, the corresponding values are 70.33, 67.33, and 70.66. A normality test shows that all test groups are not evenly distributed ($p < 0.05$); this does not meet the requirements for a one-way ANOVA test. Therefore, data analysis was performed using the nonparametric Kruskal-Wallis test to determine whether there are differences in the implant stability values between the three types of occlusal contact in the first and second months after implant placement (Table 2).

In the baseline period, statistical analysis using the Kruskal-Wallis test shows that there is no significant difference in ISQ value ($p > 0.05$) between the different types of occlusal contact. Furthermore, at the first and second months post-implantation, the Kruskal-Wallis test shows that there are significant differences in the ISQ values ($p < 0.05$) between no occlusal contact, light contact, and normal contact. Following these results, a post-hoc Mann-Whitney test is used to determine which groups have significant differences; the results are shown in Table 3.

Table 2. Differences between implant stability with different types of occlusal contacts at baseline and after the first and second months

Period	Occlusal contact	n	Occlusal contact Median (Minimum-Maximum)	p-value
Baseline	None	3	66 (66-66)	1.000
	Light	3	66 (66-66)	
	Normal	3	66 (66-66)	
First month	None	3	69 (69-69)	0.034*
	Light	3	69 (68-69)	
	Normal	3	66 (66-67)	
Second month	None	3	71 (70-71)	0.048*
	Light	3	70 (70-71)	
	Normal	3	67 (67-68)	

Kruskall-Wallis test
* statistically significant ($p < 0.05$)

Table 3. Implant stability between different types of occlusal contact after the first and second months

Month	Occlusal contact	p-value
1	None vs Light	0.317
	None vs Normal	0.034*
	Light vs Normal	0.043*
2	None vs Light	0.456
	None vs Normal	0.042*
	Light vs Normal	0.043*

Post-hoc Mann-Whitney test
* statistically significant ($p < 0.05$)

Statistical analysis using the post-hoc Mann-Whitney test shows that in the first month, there is a significant difference between the implant stability value of the groups with normal occlusal contact and no contact and the groups with light occlusal contact and normal occlusal contact. However, there is no significant difference ($p > 0.05$) between the implant stability value of the groups with normal occlusal contact and no contact. In the second month after implant placement, there is a significant difference ($p < 0.05$) between the implant stability value of the groups with normal occlusal contact and no contact and the groups with light occlusal contact and normal contact. However, there is no significant difference ($p > 0.05$) between the implant stability value of the groups with normal occlusal contact and no contact. To determine differences in implant stability value between the baseline period, first month and second month on three types of occlusal contact, a Friedman test was used (Table 4).

Table 4. Differences in implant stability values between baseline period and first and second months for three different types of occlusal contact

Occlusal contact	Period	ISQ implant value Median (Minimum-Maximum)	p-value
None	Baseline	66 (66-66)	0.050
	First month	69 (69-69)	
	Second month	71 (70-71)	
Light	Baseline	66 (66-66)	0.050
	First month	69 (68-69)	
	Second month	70 (70-71)	
Normal	Baseline	66 (66-66)	0.061
	First month	66 (66-67)	
	Second month	67 (67-68)	

Friedman test

Statistical analysis using the Friedman test showed a significant difference between the implant stability values for the baseline period and the first and second months for the groups with no contact and light contact, but not for the group with normal contact.

3.2 Discussion

This research is an analytical study with an experimental design that aims to determine the influence of occlusal contact on provisional restoration without contact, light contact, and normal contact at implant sites with immediate loading. The implant stability value is measured by the RFA method using Ostell ISQ in the baseline period and at the first and second months post-implant placement in the experimental animal, *M. fascicularis*. To achieve the objectives of this study, animal testing should follow the "principles of 3R": Replacement, Reducing, and Refinement. Following the Replacement principle, an in vitro study should be considered before using experimental animals. Following the Reducing principle, the study should use as few animals as possible and maximize the outcomes from the animals that are used. This principle is fulfilled because this study only uses three animals. Following the Refinement principle, the procedures are modified such that experimental animals feel minimal pain. This principle is fulfilled because all procedures, such as taking an impression, tooth extraction, implant placement, and measuring the implant stability, were performed under general anesthesia and were approved by an ethics committee [17]. In this study, dental implants were placed in *M. fascicularis*. *M. fascicularis* was chosen as the experimental animal because its genetics and tooth and bone structures are similar to those of humans [16]. All procedures such as implant placement and measuring implant stability were performed by one operator to avoid bias.

The implant stability was measured using the RFA method using Ostell ISQ. In the RFA method, a wave with a certain frequency is continuously applied to an implant. If an implant is stable, the resulting resonance will occur at high frequency. This frequency is translated into an ISQ value ranging from 0 to 100. The higher the ISQ, the more rigid is the contact between the implant and the bone, and therefore, the better is the stability. According to Ostell, the reproducibility of Ostell ISQ is very good (0.97) [18]. One of the objectives of implant treatment is to restore stomatognathic functions. To achieve this objective, the bone-implant contact must be stable and the load must be correct so that osseointegration will occur. Osseointegration is the contact between the bone and the implant surface that requires the formation of new bone around the implant [2].

In this study, there are significant differences in the ISQ values between implants with normal contact and no contact and implants with light contact and normal contact in the first and second months post-implantation. These findings are consistent with Miyata et al.'s study, which stated that occlusal load that exceeds physiological limits can affect the amount of bone resorption around the dental implant. This situation may occur owing to the effects of biomechanical occlusal contacts to the bone on a cellular level [19].

Bone remodeling around the dental implant is affected by bone strain. The amount of strain depends on the amount of pressure or load exerted. Similarly, with an implant, the occlusal load exerted on the implant is forwarded to contact area between the bone and the implant. The greater the occlusal load, the greater is the strain produced. If the value exceeds a physiological limit, the bone will induce the production of cytokines to start bone resorption. As a result, bone loss will occur at the contact area between the bone and the implant, and the implant stability will be reduced. This occurrence is translated as a low ISQ value with the RFA method for an implant with normal occlusal contact compared to implants with light and no occlusal contact. On the other hand, there is no significant difference in the ISQ values between implants with no contact and light contact on provisional restoration. This might happen because the load generated from the provisional restoration did not produce strain above the physiological limit that could cause bone resorption [20-21]. Furthermore, the amount of occlusal load transmitted to the implant does not depend on occlusal contacts alone. Other factors that might contribute include the number of implants, implant angulation, implant size,and bone quality [19].

Implant placement procedures such as mucosal incision and mechanical implant placement damage the mucosa and bone. Under these circumstances, compression on the cortical bone and damage to vascularity causes immediate bone formation around the implant. This bone formation, called primary stability, supports the implant stability immediately after implant placement. Over time, bone is formed at the rate of 100 μm per day in multiple directions. However, this bone has low

biomechanical capacity. After a few months, this bone will be replaced by lamellar bone, and after 18 months, the implant will achieve permanent stability. The lamellar bone will afford secondary stability to the implant [18,22]. The process of new bone formation around the implant, as described above, might be the cause of the significantly higher ISQ value at the first and second months after implant placement. The limitations of this study are the small number of samples and the lack of time to measure the implant stability owing to the large treatment and maintenance costs for experimental animals. In addition, it was also difficult to make occlusal forms of the tooth owing to its small shape and size. Another limitation of this study was the difficulty in achieving articulation with animals compared to humans.

4. Conclusion

This study aimed to analyze the influence of immediate loading on provisional restoration in dental implant stability. The following conclusions can be derived: (1) there is no significant difference in the implant stability value for implants that are placed under immediate loading right after implant placement between groups with no, light, and normal occlusal contact; (2) there is a significant difference in the implant stability value for implants that are placed under immediate loading in the first month after implant placement between groups with no and normal occlusal contact and groups with light and normal occlusal contact, but not between groups with no and light occlusal contact; (3) there is a significant difference in the implant stability value for implants that are placed under immediate loading in the second month after implant placement between groups with no and normal occlusal contact and groups with light and normal occlusal contact, but not between groups with no and light occlusal contact; (4) there is a significant increase in the implant stability value in the first and second months after implant placement between groups with no and light occlusal contact but not between groups with no and normal occlusal contact; (5) The highest implant stability value was found in groups that have no occlusal contact.

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