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Communication

Validation of the Implant Stability Test for Implant Provisional Crowns: An In Vitro Study

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Abstract: Implant treatment has evolved and is now performed using various techniques. However, the osseointegration duration required for poor primary stability or immediate loading is unclear and depends largely on the surgeon's experience. We sought to verify whether implant stability can be quantified after immediate loading, using AnyCheck®. Six implants were placed in simulated bone blocks classified by bone quality as D1–D4 and further divided into healing abutment and provisional crown groups. The implant stability test (IST) values of both groups were measured using AnyCheck®. All bone qualities from D1 to D4 differed significantly between the provisional crown and healing abutment groups ($p < 0.001$). In both groups, the IST values were the highest for D1 bone and lowest for D4 bone. There were significant differences in bone quality between the provisional crown and healing abutment groups. The correlations between the groups differed based on bone quality. However, the IST values of both groups differed by a minimum of 4 and maximum of 7. These results suggest that AnyCheck® is useful for quantifying the implant stability after immediate loading. Using an index to quantify the implant and bone stability for immediate loading may shorten treatment duration and increase success rates.

Keywords: AnyCheck®; dental implant; immediate implant; immediate loading; implant stability test; relief period

Citation: Okuhama, Y.; Nagata, K.; Nakashizu, T.; Wakamori, K.; Okubo, M.; Tsuruoka, H.; Kawana, H. Validation of the Implant Stability Test for Implant Provisional Crowns: An In Vitro Study. *Appl. Sci.* **2023**, *13*, 3947. https://doi.org/10.3390/app13063947

Academic Editor: Bruno Chrcanovic

Received: 14 February 2023
Revised: 16 March 2023
Accepted: 17 March 2023
Published: 20 March 2023

1. Introduction

In recent years, implant treatment has become widely used in dentistry. Technological improvements have enabled the treatment of various patient conditions [1–3]. In dental implant treatment, particular surface properties can help shorten the unloading period and specific morphological characteristics can promote initial fixation [4–6]. Development of these technologies has helped shorten the treatment period, allowing for immediate implant placement with immediate or conventional loading. In terms of the osseointegration period in conventional loading, the period recommended by the manufacturer is used as an index. However, the duration required for osseointegration in cases with poor primary stability or for immediate loading is not precisely known and is chosen largely based on the experience of the surgeon.

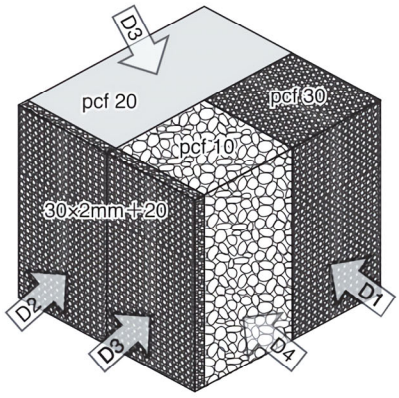
Instruments, such as the Osstell® and AnyCheck®, were developed to measure implant stability [7–9]. Osstell® has been applied in implant therapy for several years; it measures implant stability via a jig called a smart peg that is attached to the implant body [10]. The optimal time for superstructure placement for implants that receive a provisional crown immediately after placement has not been defined. Therefore, we thought that these devices could be used after the placement of the provisional crowns to shorten the treatment time. Koutouzis et al. [11] reported that bone resorption at 6 months was 0.28 mm in the group in which healing abutments were removed twice before superstructure placement using

the conventional method compared to the 0.13 mm in the group in which abutments were placed at the time of implant surgery. The removal of healing abutments or provisional crowns before osseointegration is obtained may lead to bone resorption. With Osstell, when a provisional crown is placed immediately after implant placement, the provisional crown must be removed in order to measure subsequent implant stability.

AnyCheck® measures the percussion response to the healing abutment during the recovery period and quantifies bone and implant stability. Therefore, we wondered if the stability of an implant with a provisional crown could be measured using AnyCheck®. Thus, we believe that being able to measure implant stability with provisional crowns can help reduce treatment time. The purpose of this study was to compare the stability of implants with those of healing abutments and provisional crowns using AnyCheck®.

2. Materials and Methods

Implants (Astra Tech Implant system EV® φ 4.2 mm× 13 mm; Dentsply Sirona, York, PA, USA) were placed in simulated bone blocks (Training Cube; SHOFU Inc., Kyoto, Japan) and were divided into two groups: a 4 mm healing abutment (Healing Uni EV 4.2; Dentsply Sirona) and a provisional crown group. The insertion torque was set at 30 Ncm. The training cubes were differentiated into Types I to IV based on the bone quality classification by Misch [12], and each surface had a different hardness (Figure 1).



Bone quality classification by Misch			
Bone quality	Simulated bone pcf	Feelings when using the drill	CT value
D1 (Type I)	30	Oak or Maple	＞1250HU
D2 (Type II)	30×2mm＋20	White pine or Spruce	850-1250HU
D3 (Type III)	30×2mm＋10 or 20	Balsa	350-850HU
D4 (Type IV)	10	foamed styrol	150-350HU

D1 (Type I) D2 (Type II) D3 (Type III) D4 (Type IV)

Figure 1. Training cube details. CT: computed tomography.

Twenty-four training cubes and 24 implants were used, with six implants placed in each of the Type I–IV training cubes. Three were included in the provisional crown group and three in the healing abutment group. Only one implant was placed per training cube. In addition, since this was an in vitro study, the sample size was not measured. Healing abutments are commonly hand-tightened with a screwdriver, and therefore, implants in the healing abutment group were hand-tightened [13]. The provisional crown was fastened at 20 Ncm based on the manufacturer's recommendation (Figure 2). AnyCheck® (Neobiotech Co., Ltd., Seoul, Republic of Korea) was then used to measure the IST value and to verify if there was any difference in the obtained values.

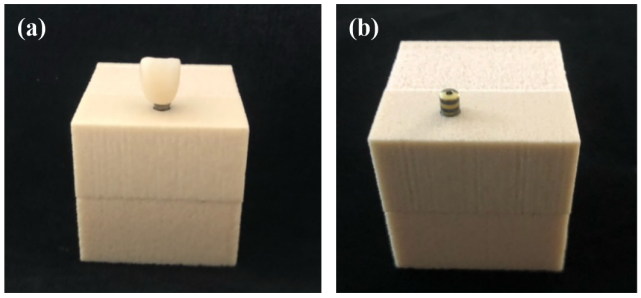


Figure 2. Creation of research models. (**a**) Provisional crown group. (**b**) Healing abutment group.

2.1. Fabrication of Provisional Crown

A laboratory analog abutment (Tru Digital Lab Analog® ASTRA TECH/EV 4.2; Dentsply Sirona) was fitted with a titanium-based NT® ASTRA TECH/EV (Dentsply Sirona). It was then scanned with a three-dimensional (3D) scanner (Ceramill Map 400®; Amann Girrbach, Pforzheim, Germany), and a provisional crown was designed using computer-aided design (Exocad®; Exocad, Berlin, Germany). Using computer-aided manufacturing (Ceramill motion 2®; Amann Girrbach), the crown was milled out of resin blocks (Asahi PMMA Disk temp, Asahiroentgen Ind. Co., Ltd., Kyoto, Japan). BeautiBond Xtreme (SHOFU Inc.) was applied to the inner surface of the provisional crown for bonding to the titanium base, and the crown was irradiated for 10 s (VALOTM Grand, Ultradent Products Inc., Tokyo, Japan). Then, using adhesive cement (ReziCem; SHOFU Inc.), the provisional crowns were irradiated for 10 s, as specified by the manufacturer, and were held in place for 10 min for chemical polymerization. Current implants often use platform switching to control bone resorption. Therefore, in the present study, provisional crowns were fabricated without an intervening intermediate structure [14]. The crown length was set at 12 mm and the crown width was set at 8 mm (Figure 3).

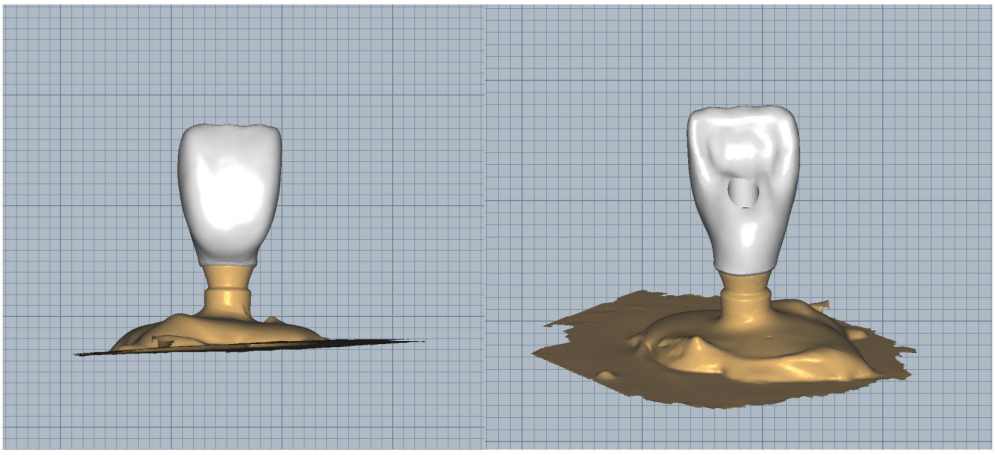


Figure 3. Design of provisional crown. IST: implant stability test.

2.2. Measurement of the IST Value

The IST values are set such that implants with values of 0–59 are not recommended for loading, while implants with values of 60–99 are loadable, with good stability. When using AnyCheck®, the healing abutment is struck six times within 3 s, the contact time is measured, and the IST value is calculated. In this study, we measured the IST values for the healing abutment and provisional crown groups. For the healing abutment group, the contact angle was set in the range of 0° to 30°, which is in accordance with the manufacturer's recommendation. For the provisional group, since there was no recommendation, a similar range was used for the measurements. AnyCheck® sets the standard height of the healing abutment as 4 mm, but when a height other than 4 mm is used, the values are

corrected as shown in Table 1 [9]. Three measurements were taken for each implant, and the average value was used in the analysis.

Table 1. Implant stability test value corrections based on the healing abutment height.

Healing Abutment Height	IST Value
7 mm	+6
6 mm	+4
5 mm	+2
4 mm	±0
3 mm	−2
2 mm	−4
1 mm	−6

IST: implant stability test.

2.3. Statistical Analysis

We used Student's t-test to compare the provisional crown and healing abutment groups using BellCurve for Excel (Social Survey Research Information Corporation, Tokyo, Japan). *p*-values of <0.05 were considered significant. Between-group comparisons were only performed according to bone quality. Correlation analysis was then performed to evaluate the correlation between the provisional crown and healing abutment groups at each bone type.

3. Results

The IST values for the two groups according to bone quality are shown in Table 2. In the provisional crown group, the IST values based on bone quality were as follows: D1, 71.9 ± 1.62; D2, 68.7 ± 1.58; D3, 65.1 ± 0.93; and D4, 56.6 ± 1.24. In the healing abutment group, the IST values were as follows: D1, 78.9 ± 1.54; D2, 74.3 ± 2.96; D3, 71.6 ± 0.89; and D4, 60.6 ± 1.33. There was a significant difference between the provisional crown and healing abutment groups for all bone quality types from D1 to D4 ($p < 0.001$; Figure 4). The Spearman's rank correlation coefficients were 0.2, 0.03, 0.67, and 0.31 for D1, D2, D3, and D4 bone types, respectively. Little correlation was observed between the groups for D1 and D2, a strong correlation was observed for D3, and a slight correlation was observed for D4. For both groups, D1 had the highest IST value and D4 had the lowest.

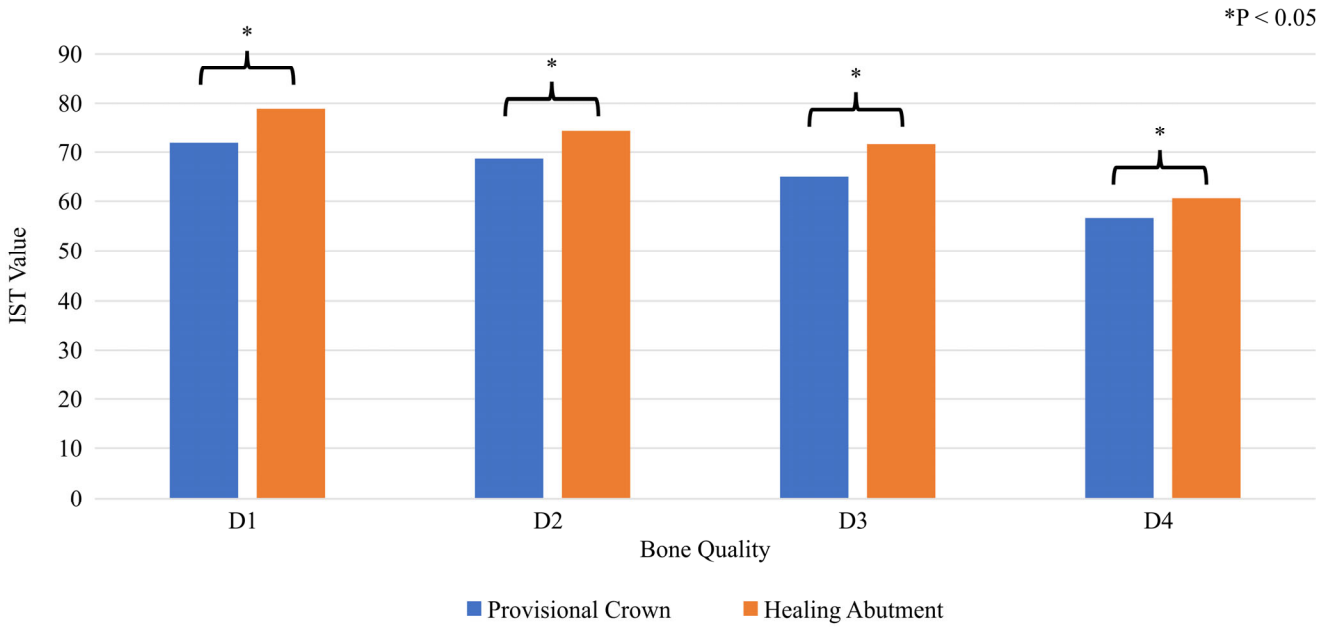


Figure 4. Comparison of the IST value of both groups by bone quality. IST: implant stability test.

Table 2. Mean and standard deviation of IST by bone quality.

Provisional Crown	D1	D2	D3	D4	Healing Abutment	D1	D2	D3	D4
Mean	71.9	68.7	65.1	56.6	Mean	78.9	74.3	71.6	60.6
SD	1.62	1.58	0.93	1.24	SD	1.54	2.96	0.89	1.33

IST: implant stability test; SD: standard deviation.

4. Discussion

The results of this study showed significant differences between the two groups for all bone quality types. The correlation varied greatly, depending on the quality of the bone. In both groups, the higher the bone quality, the higher the IST value, and the softer the bone, the lower the IST value. The difference between the two groups was a minimum of 4 and a maximum of 7.

Makary et al. [15] measured the implant stability quotient (ISQ) of 40 implants in 14 patients at each week from the time of placement up to 4 weeks. The primary stability and ISQ values were 107.2 ± 35.6 Ncm (ISQ: 81.9 ± 2.0), 74.7 ± 14.0 Ncm (ISQ: 81.1 ± 1.0), 76.5 ± 31.1 Ncm (ISQ: 78.3 ± 3.7), and 55.2 ± 22.6 Ncm (ISQ: 73.2 ± 4.9). These results indicated that the harder the bone quality, the higher the ISQ value, which is consistent with our results. The primary stability was found to vary depending on the bone quality and implant shape [16,17].

In immediate loading, initial fixation is one of the factors for successful treatment. Benic et al. [18] compared the immediate load and conventional loading of single implants. They reported that the initial fixation for all implants had a torque of ≥20–45 Ncm, ISQ ≥ 60–65, and there was no significant difference in implant survival and marginal bone volume. Mijiritsky et al. [19] placed single implants with immediate loading in 15 patients. They reported that the initial fixation was of more than 32 Ncm, and the 18-year survival rate was 100%. Douglas de Oliveira et al. [20] investigated the survival rate of immediately loaded implants placed with 30 Ncm torque. They reported that the implant survival rate was 96.8% based on a review of 589 references. Maló et al. [21] performed all-on-4 implants in 83 patients. They reported a survival rate of 98.3% for 120 implants placed with less than 30 Ncm torque and of 97.5% for 212 implants placed with more than 30 Ncm torque. From these reports, it can be inferred that the initial fixation for immediate loading should have a torque of 30–45 Ncm. A systematic review by Darriba et al. [22] reported that immediate loading of 35 Ncm or less is associated with a survival rate of 96% at the 24-month follow-up. Immediate loading has shown good survival rates, allowing surgeons and patients to have a wider choice of treatment options.

After immediate loading, the decision of when to place the superstructure is a troublesome issue for the surgeon. If it is performed too early, osseointegration may not be achieved, and if it is performed too late, the temporary crown can fracture and cause an imbalance in occlusion. In addition, peri-implant mucositis or peri-implantitis may occur due to plaque accumulation [23,24]. Cannizzaro et al. [25] reported superstructure placement 6 weeks after implant placement in 50 patients who underwent immediate loading. Alfadda et al. [26] placed four implants at 35 Ncm or more and performed immediate loading in 20 edentulous mandibular patients. They reported that the final prosthetic device was placed 3 months after implant placement, with a good 10-year prognosis. Mitsias et al. [27] performed immediate loading on 18 single-tooth, partial-tooth, and edentulous patients, and placed the final prosthetic device 4 months after implantation, with good results. Lopes et al. [28] performed all-on-4 implant treatment in 23 patients and placed the final prosthetic device 3 months after implant placement. The total number of implants placed was 92, and the 5-year prognosis was 96.6%. Toljanic et al. [29] placed six implants in 40 edentulous maxillary patients and performed immediate loading. They reported that the total number of implants placed was 232, the superstructure was in place within 24 weeks of implant placement, and the 5-year survival rate was 93%. Thus, the timing of superstructure placement after immediate loading varies, although it may be related to the

number of implants placed and the surgical technique used. Quantifying the implant stability using AnyCheck® may help shorten the treatment time and prevent treatment failure.

To date, only a few reports on AnyCheck® have been published because it has been recently introduced in the market. In a clinical study, Al-Jamal et al. [30] measured the correlation between preoperative bone density and initial fixation using AnyCheck® for 40 implants. They reported significant correlations among bone density values, IST values, and insertion torque. We measured the correlation between AnyCheck® and Osstell® findings for 15 implants in 10 patients. The measurement period for each device was set immediately and 1, 2, 3, 4, and 6 weeks after implant placement. The IST values immediately and 1, 2, 3, 4, and 6 after implant placement were 81.0 ± 2.82, 79.1 ± 2.87, 79.7 ± 2.83, 80.5 ± 2.71, 80.9 ± 4.0, and 82.4 ± 2.65, respectively, with Spearman's rank correlation coefficients of 0.64, 0.29, 0.68, 0.53, 0.68, and 0.56, respectively. The IST and ISQ values were positively correlated at all time points except week 1, when the correlation was weak [9]. Lim et al. [31] measured the correlation between AnyCheck® and Periotest findings for 50 implants. Measurements were taken on the day of surgery; 2 weeks after surgery; and 1, 2, and 3 months after surgery, and the IST values were 76.1, 75.82, 76.4, 76.5, and 77.48, respectively, with no significant difference at any time point. Collectively, these findings suggest the usefulness of AnyCheck®.

No previous study has compared healing abutment and provisional crown groups using AnyCheck®. The significant difference between the two groups in the present study may be because the percussion response was directly transmitted to the implant body in the healing abutment group, but the presence of the titanium base in the provisional crown group may have interfered with the response, resulting in a lower IST value. The correlation between the groups varied with bone quality. One reason may be the small denominator. In addition, there are no reports on implant stability using training cubes; therefore, further validation is needed to increase the denominator.

However, because the difference between the two groups was a minimum of 4 and a maximum of 7, we believe that the measurement of implant stability is possible by establishing a reference value for immediate loading. Clinical application will become possible in the future when additional clinical data on immediate loading are collected.

5. Conclusions

The correlations between the two groups differed with bone quality in the present study. However, considering that the minimum and maximum difference in IST values for each group is 4 and 7, respectively, it is possible to determine the stability of implants with provisional crowns with the AnyCheck® by setting a reference IST value for provisional crowns. This may help shorten treatment times and the time taken for superstructure placement after immediate loading in the future.

Author Contributions: Conceptualization, H.K. and K.N.; methodology, Y.O., K.W. and T.N.; formal analysis, M.O. and H.T.; writing—original draft preparation, Y.O. and K.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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