Correlation of Implant Stability Between Two Noninvasive Methods Using Submerged and Nonsubmerged Healing Protocols: A Randomized Clinical Trial

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Various invasive and noninvasive methods have been used for measuring primary implant stability. Periotest damping device and resonance frequency analysis with the Osstell device have been classified as noninvasive methods. Primary and secondary implant stability measurements using both devices have given reproducible quantitative values. In this clinical randomized trial, a general correlation was evaluated between the implant stability recorded using both Osstell and Periotest devices on the day of implant installation and 3 months after healing for the submerged and nonsubmerged loading protocols. The present study also investigated whether the difference in gender of the included patients would have an effect on the correlation between the two devices. Eighty completely edentulous patients were recruited, and all patients ranged from 50 to 69 years of age. Overall, 56 men and 24 women were included, with a mean age of 62.5 years for men and 59.6 years for women. A single implant was installed in the midline of the completely edentulous mandible to improve retention of the patient's lower denture. After implant installation, one implant stability quotient (ISQ) value at the buccal surface was recorded, and then the Periotest M device was used to measure the damping effect (Periotest value [PTV]) of the installed implant using the smart peg screwed to the implant. Patients were then randomized into 2 groups using sealed envelopes: the submerged and nonsubmerged groups. For both groups, all ISQ and Periotest readings were recorded in the patient's case report file on the day of implant installation and 3 months after healing. When the ISQ of the buccal surface was correlated to the PTV, there was a moderate negative statistically significant correlation between the 2 readings (correlation coefficient = −.466, $P = .000$). There tended to be a weak negative correlation between the 2 devices in the male group (correlation coefficient = .395, $P = .046$) during implant installation, although there tended to be no correlation between the 2 devices in the female group (correlation coefficient = −.367, $P = .342$). After 3 months of healing, when correlating the readings of the buccal surface of the Osstell with that of the Periotest within each group (submerged and nonsubmerged), there was no statistically significant correlation between the readings within each group (correlation coefficient = −.014, −.430, $P = .942$, $P = .052$, respectively). However, there was a strong negative statistically significant correlation between the 2 devices for the female group for both the nonsubmerged group (correlation coefficient = −.823, $P = .003$) and submerged group (correlation coefficient = −.857, $P = .014$), whereas there was no statistically significant correlation within the male group for both the nonsubmerged group (correlation coefficient = −.377, $P = .123$) and submerged group (correlation coefficient = −.022, $P = .940$). The correlation between the Osstel and Periotest device remains controversial. The present study concluded that there is a significant negative correlation between the 2 devices when recording primary implant stability, although this significance is lost after 3 months of loading when recording secondary implant stability. Gender also affects the implant stability recording, which is mainly due to the difference in bone density between men and women.

Key Words: dental implant, stability, Osstell, Periotest, correlation, submerged, nonsubmerged loading protocol, gender

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Introduction

Dental implants have become one of the most widespread, reliable treatment options in replacing missing teeth to restore both function and esthetics.[1] One of the important criteria for a successful osseointegration of dental implants is achieving good primary and secondary implant stability.[2–4] Primary implant stability has been defined as the absence of implant mobility immediately

after installation,[5] which is achieved by mechanical interlocking between the installed implant and the surrounding bone.[6] Many factors will influence the primary stability of dental implants, including the implant material used, microscopic and macroscopic morphology of the implant, bone quality/quantity, cortical thickness,[7] and the surgical technique used for implant placement,[8] whereas secondary stability depends on both bone formation and the bone remodeling around the implant-bone interface. Secondary implant stability is also influenced by the implant surface and bone-healing time, which is initiated at the implant-bone interface during the healing phase.[9]

A good primary implant stability is considered to be not only an essential criterion for successful osseointegration but also a key factor for the selection of the loading protocol to be followed,[10] and it is a crucial factor in the decision of immediate loading.[5,11,12]

Various invasive and noninvasive methods have been used for measuring primary implant stability, including histomorphometric analysis, tensional tests, push/pull-out tests, insertion and removal torque tests, percussion tests, radiographic analysis, damping capacity assessment using the Periotest device, and resonance frequency analysis (RFA) using the Osstell device.[13–23]

The Periotest damping device and RFA with the Osstell device have been classified as noninvasive assessment methods.[24,25] Primary and secondary implant stability measurements using both devices have resulted in reproducible quantitative values.

The Periotest device was first introduced by Schulte in 1983[26] and was originally designed to measure the signs of stress absorption around the periodontal ligament of natural teeth as a measure of mobility.[27] However, it has recently been used to measure the stability of dental implants. Zix et al[28] demonstrated that Periotest is a reliable tool to detect changes around the bone implant surface, and Aparicio et al[29] and May et al[30] have used Periotest readings to determine the success of osseointegration. The Periotest is a handheld device that consists of a small computer with a handpiece that has a tapping rod on the inside, which is electromagnetically driven. The tapping rod contacts the tooth or implant, and the contact time between the tapping rod and the implant or teeth is calculated as the Periotest value (PTV), which ranges from −8 (low mobility/good stability) to +50 (high mobility/low stability) PTV units.

The Osstell device uses RFA to measure implant mobility and stiffness, which is interpreted as the implant stability quotient (ISQ) value, which ranges from 1 (low stability) and 100 (highest stability). First studies using frequency resonance analysis was carried out by Meredith et al.[22] The Osstell device used was an electronic fork that converts kilohertz to ISQ values. Recently, the new magnetic RFA has a transducer, which is a metallic rod with a magnet on top that is screwed to the abutment or implant. The magnet is excited by a magnetic pulse from a wireless probe. After excitation, the peg vibrates freely, and the magnet induces an electric voltage in the probe coil. That voltage is the measurement signal sampled by the resonance frequency analyzer, which provides the ISQ value. RFA have been used to evaluate changes in the healing patterns for different loading protocols during the initial weeks of implant healing.[12]

In this clinical randomized trial, the general correlation was evaluated between the implant stability recorded using both the Osstell and Periotest devices at the day of implant installation and 3 months after healing for 2 loading protocols, submerged (S) and nonsubmerged. We also investigated whether the difference in the number of men and women had any effect on the correlation between the 2 devices.

Materials and Methods

The study proposal was approved by the Ethical Committee on June 13, 2016 (ethical approval No. 16/6/10) and is registered at http://www.pactr.org/ (trial PACTR201803003085193). The guidelines of the World Medical Association were implemented in this clinical trial. A proper medical history for each patient was documented, and in most cases, referral letters to the patient's physician were provided if there were any precautions during implant installation. Furthermore, to orient the patients regarding the procedure, all clinical steps were explained to the patients using video illustrations similar to the procedure to be carried out, and all the necessary precautions were written down for patients to follow (eg, instructions regarding postoperative pain medications after implant installation). All necessary assurance was provided to the patient that in the case of any discomfort or complications, the patient would be directed to the university hospital and all necessary procedures would be carried out. Appropriate compensation and treatment for all patients participating in this study was ensured; for example, in the case of postoperative complications following implant installation, such as swelling or pain, the patient would be followed up, and if the patient required implant removal, a new implant would be installed after proper healing for the patient's benefit, despite the fact that the patient had been excluded from the research. All patients were followed up every 3 months during the first year to record any complications. All selected patients were aware of the treatment provided and had some level of scientific background and awareness to comply with all instructions given. The laws and regulations of the country in which the research was performed were strictly followed.

The procedures were properly explained to all patients, and informed consent was signed. For patients who were incapable of providing informed consent, the patient's family was involved for further clarification. The patient was required to agree to follow all procedures.

The implants used in the current trial have been used in previous clinical trials; thus, there was no harm or risk for such an intervention.

Sample size calculation

We calculated the sample size out based on the work by Zix et al.[28] A correlation coefficient of −.65 was used, and for the nonsubmerged group, an estimate based on expert opinion of −.10 was used. We used a Z test and 2 independent Pearson correlations with G*power 3.1.9.2 (alpha significance = .05,

Table 1

Inclusion and exclusion criteria of the randomized clinical trial

Inclusion criteria
Completely edentulous male or female patients between the ages of 50 and 69 y
No contraindications for implantation
Each patient must undergo both a random blood glucose and glycosylated hemoglobin analysis. Patients with a glycosylated hemoglobin level of up to 8%[31] and a normal blood glucose level (79–110 mg/dL) or controlled diabetes (90–130 fasting according to American Association of Diabetes) were included.
Sufficient bone width (≥5 mm) in the anterior region to place an implant. This could be either normally present or achieved by bone plateauing. This was confirmed by cone-beam computerized tomographic scans.
Residual bone height of 11–20 and 13 mm at the lowest vertical height of the mandible and the lowest vertical bone height in the midline of the mandible, respectively; Class II or III according to McGarry et al.[32]
Patients seeking to install a single median implant in the mandible and for whom new dentures will be constructed
Patients who are dissatisfied with the retention and stability of their technically satisfactory mandibular dentures
Patients who already have existing maxillary and mandibular complete dentures, and after examination of the mandibular dentures, it is found that there are technical problems with regard to denture design and/or occlusion; new maxillary and mandibular dentures will be fabricated
All patients should have adapted to their dentures for at least 6 weeks before being included in the trial.
All patients should provide a written consent to participate in the trial, and this will be done before the scheduled date for implant installation.
Exclusion criteria
A minimum insertion torque of 30 Ncm and/or a minimum implant stability quotient of 60 ISQ are not achieved
Allergic reaction to titanium
Serious complication after implant placement
Any relevant deterioration in the health of the subject possibly affecting participation in the trial
Failure of the participant to comply with trial requirements
Withdrawal of consent

power = 80%, effect size = −.6749634). The total sample size was 38 in each group, resulting in a total of 76 patients.

Patient recruitment

Strict inclusion and exclusion criteria were set for patient recruitment (Table 1). All patients fulfilling the inclusion criteria were listed with a number starting from 1, and the first 80 patients were included in the study (simple random sampling).

We recruited 80 completely edentulous patients, and all patients were seeking to install implants in the mandible to improve the retention of their mandibular complete dentures. Patients ranged in age from 50 to 69 years. Overall, 56 men and 24 women were included in this clinical trial, with a mean age of 62.5 years for men and 59.6 years for women.

Any systemic conditions that were a contraindication to implant placement were considered to be an exclusion criterion. A glycosylated hemoglobin analysis was mandatory for all included patients, and those with a glycosylated hemoglobin level greater than 8% were excluded from the study. An informed consent had to be signed and approved by all patients before implant installation.

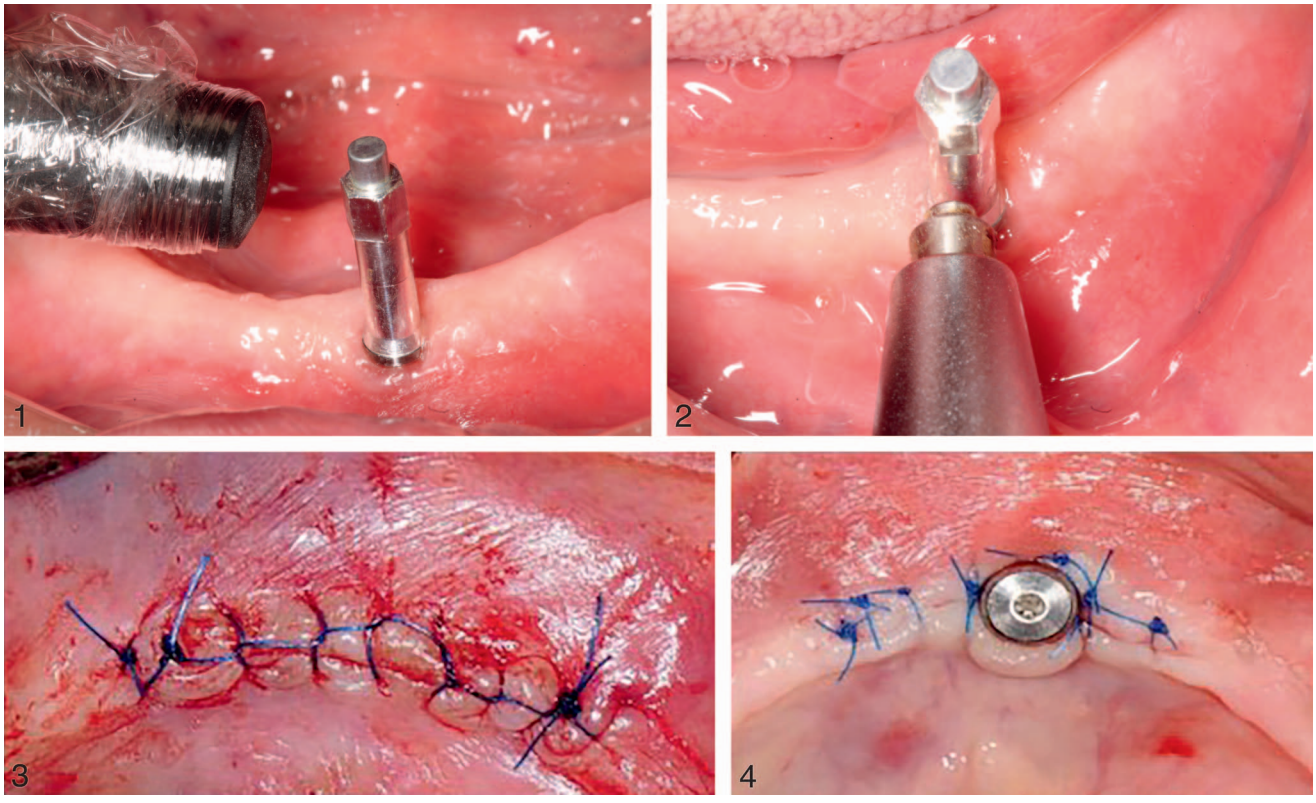
All included patients had either newly fabricated upper and lower dentures or previous dentures that were checked for retention, stability, and proper occlusion. All patients were ready for implant installation after a 6-week period of adaptation with their newly fabricated dentures.

All complete dentures were then duplicated to fabricate transparent radiographic stents, with radio-opaque acrylic resin placed in the anterior incisors areas. Patients were then referred to the Oral and Maxillofacial Radiology Department for cone-beam computerized tomography examination, which was performed while the patient was wearing the clear transparent radiographic stent with radio-opaque markers. Patients were then ready to receive the installation of one implant in the midline of the mandible.

Implant installation

Patients were instructed to take a dose of 2 g of amoxicillin 2 hours before surgery. Local anesthesia was given in the lower anterior area, then a small crestal incision was made in the area of implant installation, guided by the radiographic stent, which was converted to a surgical stent at the day of surgery. The surgical stent had a small opening in the area corresponding to the central incisors to help in implant installation. All implants installed in this study were ZDI implants with a tapered screw vent (Zimmer Dental, Warsaw, Ind), with a diameter of 3.7 mm and length of 10 mm. Drilling was carried out using the Zimmer Dental kit following the manufacturer's instructions. To omit the human variable error, a single prosthodontist carried out all implant installations for all patients. The ISQ was measured for all installed implants using the Osstell device (Osstell, Integration Diagnostics Ltd, Sävedalen, Sweden). A smart peg was screwed to the installed implant, and 1 ISQ value for the buccal surface was recorded (Figure 1). The measuring probe of the Osstell device had to be held at a distance of 1–3 mm from the smart peg at an angle of 90°, 3 mm above the soft tissue, as described by the manufacturer. Implants with an ISQ value of less than 60 were excluded from the study, because an ISQ value of 60 and higher was considered to be one of the inclusion criteria.

After implant stability measurement using the Osstell device, the Periotest M (Medizintechnix Gulden e.K., Modautal, Germany) device was used to measure the damping effect of the installed implant using the smart peg screwed to the implant. The Periotest M was used on the mid-buccal surface perpendicular to the long axis of the screwed smart peg away from the magnetic portion, as described by the manufacturer,



Figures 1–4. Figure 1. Ostell reading recorded using a smart peg. **Figure 2.** Periotest reading recorded using a smart peg. **Figure 3.** Submerged healing protocol. **Figure 4.** Nonsubmerged healing protocol.

and 1 reading was recorded (Figure 2). All ISQ and Periotest readings (PTV) were recorded in the patient's case report file on the day of implant installation, which was considered to be the baseline readings. The smart peg was then unscrewed from the installed implant and placed in the patient's file.

After implant stability measurements, the patients were randomized using sealed envelopes into 2 groups: the submerged and nonsubmerged healing groups. For the submerged group, the flap was sutured, and tight closure was ensured (Figure 3), whereas for the nonsubmerged group, a healing abutment of proper height was screwed to the implant, and the flap around the healing abutment was sutured (Figure 4). For both groups of patients, the fitting surface of the denture was modified and relined using soft liner GC Soft-Liner (GC Corporation, Tokyo, Japan). All patients were recalled after 1 week for suture removal and further modification of the denture.

At the end of the healing phase (before the second randomization), 6 patients reported failure, 2 patients in the nonsubmerged group and 4 patients in the submerged group. Three dropouts were recorded during the healing phase, all of which were from the submerged group (Figure 5). Some patients (6 in the submerged group and 9 in the nonsubmerged group) refused to screw the smart peg for the Osstell measurements, because they were convinced that this recording would make the implants subjected to extra loads (Figures 5 and 6; Table 2).

A total of 56 patients were present at the end of the 3-month healing period. All patients were recalled, and the Osstell and PTV values were recorded before the pick-up step.

All ISQ readings of the buccal surface and the Periotest M readings were collected and put in tables, and a general correlation between the Osstel readings and Periotest M readings were statistically analyzed to detect if there was a general correlation between the 2 device readings with regard to the primary implant stability on the day of implant installation and 3 months after healing.

Data management and statistical analysis were performed using Statistical Package for Social Sciences (SPSS) version 21. Data were explored for normality using the Kolmogrov-Smirnov test and Shapiro-Wilk test. Correlation between various variables was determined using the Pearson moment–correlation equation for the linear relation of normally distributed variables and the Spearman rank correlation equation for nonnormal variables/nonlinear monotonic relation. Two-sided *P* values less than .05 were considered statistically significant. All statistical calculations were performed using IBM SPSS (IBM Corp, Armonk, NY) release 22 for Microsoft Windows. An alpha significance of .05 and power of .80 were used in this clinical trial.

Results

During implant installation

When correlating the values of the Osstell and Periotest readings of the buccal surface during implant installation, there was a moderate negative statistically significant correlation between the 2 devices for all 80 patients (correlation coefficient = −.466, $P = .000$; Table 3; Figure 6).

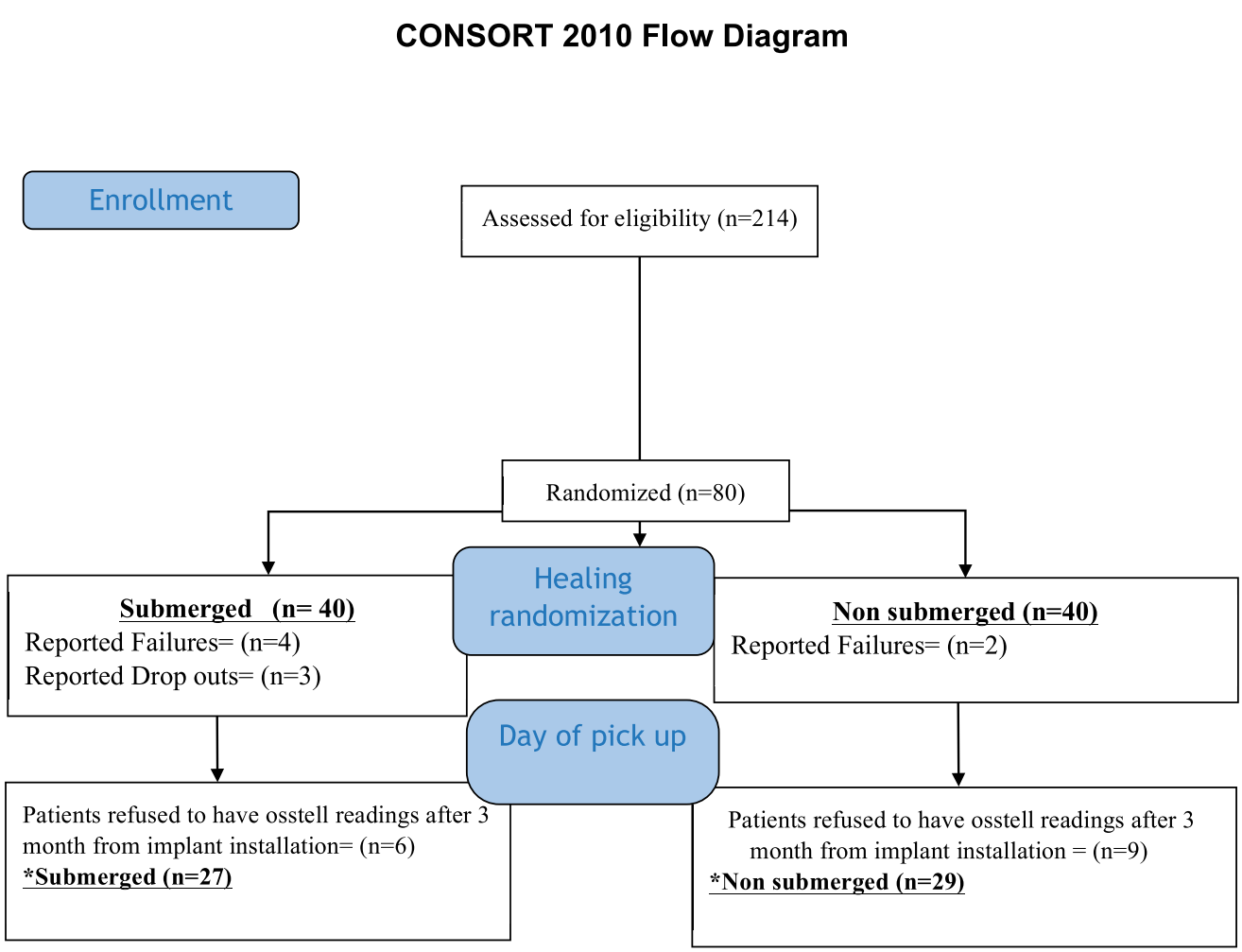


Figure 5. Consort flow diagram.

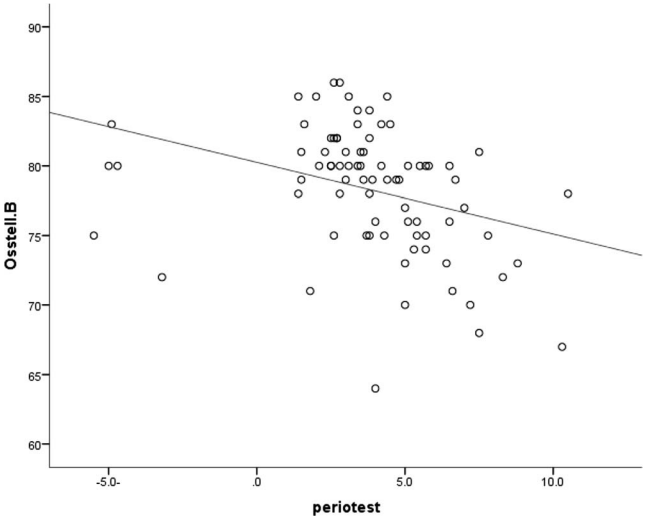


Figure 6. Negative correlation between the Osstell readings at the buccal surface and the Periotest readings, which was statistically significant at $P \leq .005$.

Effect of gender on the correlation between the 2 devices during implant installation

The number of women in this study was 24, and the number of men was 56. In the female group, there tended to be no correlation between the 2 devices during implant installation (correlation coefficient = −.367, P =.342). However, in the male group, there tended to be a weak negative statistically significant correlation between the 2 devices (correlation coefficient = .395, P = .046; Table 4).

Correlation between the two devices after 3 month healing period

In both groups (nonsubmerged and submerged), there tended to be a nonstatistically significant correlation (no correlation) between the 2 devices (correlation coefficient = −.014, −.430, P = .942, P = .052, respectively; Table 5).

Effect of gender on the correlation between the 2 devices for the nonsubmerged and submerged groups

There tended to be a strong negative statistically significant correlation between the 2 devices for the female group for both the nonsubmerged group (correlation coefficient = −.823,

TABLE 2

Number of women and men throughout the study

	Nonsubmerged		Submerged	
	Men	Women	Men	Women
During implant installation (start of the study	26	14	30	10
Failures	2	—	2	2
Dropouts	—	—	3	—
Patient who refused readings after 3 mo	6	3	5	1
Total	18	11	20	7

$P = .003$) and the submerged group (correlation coefficient = −.857, $P = .014$), whereas in the male group, there was a non–statistically significant correlation (no correlation) between the 2 devices (nonsubmerged, correlation coefficient = −.377, $P = .123$; submerged, correlation coefficient = −.022, $P = .940$; Table 6).

Discussion

The increased demand for a noninvasive technique to detect and monitor implant stability has resulted in the increased usage of the Osstell and the Periotest devices. Many factors influence the accuracy of recording primary implant stability, including bone quality and quantity, implant length, implant diameter, area of implant installation, and the height of the abutment to be measured.

Zix et al[28] attempted to assess the correlation between the two devices clinically, using implants with different diameters and lengths that were installed in both the mandible and maxilla. It was concluded that the Osstell device is more precise than the Periotest device, and they recommended future clinical trials to investigate the correlation of both devices for the same set of implants over a fixed time. Therefore, the main aim of the present study was to find a correlation between the Osstell readings and Periotest readings by keeping all of the factors as constant as possible over the 3-month healing period. Implants with the same length and diameter (3.7 mm × 10 mm) were installed in the midline of the mandible, and primary implant stability was recorded using the same smart peg screwed to the implant, in which the ISQ values and PTV values were recorded. In addition, only one prosthodontist installed all implants for all patients.

For both devices, the interoperator and interinstrument variables were difficult to control. For the Periotest recording, the instrument in this study was held horizontally at the mid-buccal surface of the screwed smart peg at the bottom (away) from the magnetic portion of the smart peg, with a valid distance of 0.6–2.5 mm between the tapping rod to the smart peg surface, as recommended by the manufacturer. Olive and Aparicio[33] reported that Periotest readings were sensitive to the position of the tapping rod application on the surface of the abutment and the angulation by which the instrument was held: a change in position of 1 mm of the Periotest striking may change the PTV readings between 1 and 2. Therefore, all efforts were made to fix the distance and angulation when using the Periotest device. A study carried out by Bilhan et al[34] indicated that only Periotest measurements from the buccal surface resulted in excellent intra- and interobserver reliability for recording the implant stability, which is why we used only the buccal surface readings in the present study. For the Osstell device, per the manufacturer's instructions, the measuring probe had to be held at a distance of 1–3 mm from the smart peg at a 90° angle 3 mm above the soft tissue; the buccal surface was recorded only to correlate it with the same surface recorded using the Periotest device.

The number of men and women included in this study was not equally distributed, with more men than women. This was another variable that was difficult to control, as the recruitment was carried out using a list, and the first 80 patients were included. When trying to investigate whether men and women would affect the correlation between the 2 devices, it was found that during implant installation, there was a weak negative statistically significant correlation between the 2 devices, whereas for women, no significant correlation was present. A reason for this could be the greater number of men compared with women, and another reason could be that the primary implant stability was higher in men. A study by Ostman et al[35] concluded that greater implant stability was observed in

TABLE 3

Correlation between the buccal surfaces of the Osstell readings and the Periotest readings*

Spearman rho, Periotest Installation	Osstell Installation
Correlation coefficient	−.466
P	.000
n	80

*Statistically significant at $P \leq .005$.

TABLE 4

Effect of women and men on the correlation between the 2 devices during implant installation*

Spearman rho, Periotest Installation	Osstell Installation
Women	
Correlation coefficient	−.367
P	.342
n	24
Men	
Correlation coefficient	−.395
P	.046
n	56

*Statistically significant at $P \leq .005$.

Table 5

Correlation between the 2 devices after a 3-month healing period for the nonsubmerged and the submerged group*

Spearman's rho, Periotest-3m	Osstell-3m
Nonsubmerged group	
Correlation coefficient	−.014
P	.942
n	29
Submerged group	
Correlation coefficient	−.430
P	.052
n	27

*Statistically significant at $P \leq .005$.

men than in women, and this would mainly be due to the difference in bone density between men and women. Friberg et al[36] reported that there is a positive correlation between implant stability and bone density, so the male group in this clinical trial likely had higher bone density with higher implant stability than women did. After a 3-month healing period in both groups, the submerged and nonsubmerged female group showed a strong statistically significant negative correlation between the 2 devices. Most of the women included in the present study between the ages of 50 and 69 years, and those patients might have suffered from osteoporosis or hormonal changes due to menopause, which affects bone mineral metabolism and consequently decreases bone quality when compared with men. Zix et al[37] reported that women have lower ISQ values than men, and this finding was related to the postmenopausal state of women, which compromises bone density. After 3 months of healing after implant installation, the implant stability in the female group could have improved when compared with the male group; this improvement was reflected by a strong correlation between the 2 devices, despite the lower number of women in both groups, which suggests that implant stability significantly improved, leading to a significant correlation between the 2 devices. Few clinical trials have reported a difference in implant stability based on gender. Balshi et al[38] reported that men have a significantly higher implant stability than women, and after 90-day follow-up, this difference was not significant, Ostman et al[35] reported that the difference in implant stability with regard to gender was not clinically significant, as there was no difference in failure rates between men and women. Further studies reporting age and the ISQ readings throughout the osseointegration process for men and women are needed, as this could affect the treatment plan of postmenopausal women with respect to immediate loading, which would require longer healing periods.

When the Osstell readings and Periotest readings were correlated in this clinical trial, we found a statistically significant negative correlation between the readings. This is in agreement with a clinical study conducted by Oh and Kim[10] and a systematic review by Andreotti et al,[39] who found a significant negative correlation between ISQ and PTV readings and that both devices can be used to predict primary stability and loading protocols. Furthermore, in vitro studies[40–42] on human cadavers and animals revealed good negative correlations between ISQ and PTV.

Table 6

Effect of women and men on the correlation between the 2 devices for the nonsubmerged and submerged*

Spearman's rho, Periotest-3m	Osstell-3m
Women nonsubmerged	
Correlation coefficient	−.823
P	.003
n	11
Men nonsubmerged	
Correlation coefficient	−.377
P	.123
n	18
Women submerged	
Correlation coefficient	−.857
P	.014
n	7
Men submerged (S)	
Correlation coefficient	−.022
P	.940
n	20

*Statistically significant at $P \leq .005$.

In their in vitro study, Winter et al[43] concluded that there was a good correlation between the Periotest and Osstell readings for recording primary implant stability, provided there was no simulated bone height change or loss. Furthermore, Pang et al[44] reported a strong correlation between the ISQ and PTV after surgery, whereas at 3 and 15 months postoperatively, the relationship between the values was weak. This provides an explanation as to why there was no correlation between both devices after a 3-month healing period in both the submerged and nonsubmerged groups.

Osseointegration and the stability of dental implants are mainly characterized by the deposition of bone in close contact to the implant interface. The deposition of bone takes place throughout different stages, starting from woven bone deposition between the implant threads and then the transformation to lamellar bone, which is more mineralized and organized. The adaptation process is influenced by implant material, surface treatment, and loading. In the present clinical trial, the submerged and nonsubmerged groups were subjected to different loads of various magnitudes during the healing period, and the nonsubmerged group had a healing abutment. Although there was sufficient relief between the healing abutment and the fitting surface of the denture, the nonsubmerged group was exposed to more loads than the submerged group. The different loads for both groups had an effect on the remodeling of the underlying bone, which could directly affect the secondary stability. Therefore, there tended to be no correlation between the 2 devices for the 2 groups after the 3-month healing period, mainly because of the difference in adaptation of the underlying bone.[43]

The Periotest device has been shown to be more sensitive to intraobserver and intraoperator errors, which have made its reliability questionable when compared with the Osstell device.[23] However, the Periotest device is able to measure the primary implant stability directly at the abutment, because it does not require the use of a smart peg to be screwed to the implant, as the Osstell device does.

There is no consensuses or standardization in the classification of implant stability between the Osstell and Periotest devices; therefore, despite the fact that both devices may provide reliable results, there is always no agreement between them.[39] Therefore, from a clinical point of view, when monitoring implant stability, it is preferred to assess the progress using only a single device.

Conclusion

The correlation between the Osstel and Periotest devices is a controversial issue, the present study concluded that there is a significant negative correlation between the 2 devices when recording primary implant stability. However, this significance is lost after 3 months of loading when recording secondary implant stability. Gender was found to affect the implant stability recording, which is mainly attributed to the difference in bone density between the men and women.

Limitations of the study and further recommendations

One limitation of this study was that all implants used were of the same length and diameter, and all implants were installed in the mandible, despite the fact that this was a point of strength in this study. However, if implants of different diameters and lengths and different sites of installation are implemented, the correlation between the 2 devices over a set period of time (3 month of healing) would probably yield different results.

A further limitation of this study is that the smart peg was used to record the implant stability using both devices; the Periotest was applied at the bottom of the smart peg away from the magnetic portion, whereas the Osstel device was directed at the top part of the magnetic portion. This difference in the application of both devices may affect the readings, so 5 readings for each device should probably have been considered, because an average of 5 readings will omit the variable. One reading was recorded for convenience, especially on the day of implant installation, because some patients during the implant installation surgery would not have approved of having several readings. In addition, because the tapping motion of the Periotest can affect the osseointegration of the implant, only one reading was recorded at implant installation and after 3 months of healing for consistency.

To add to the conclusions of this study, future clinical trials should investigate the correlation between the 2 devices and also report other clinical parameters such as bone height changes, soft-tissue healing, and changes in the peri-implant tissues as well as patient-related outcomes during the healing period. In addition, future randomized clinical trials assessing the difference in implant stability between men and women over the period of osseointegration are recommended.

Abbreviations

ISQ: implant stability quotient

PTV: Periotest value, damping effect

RFA: resonance frequency analysis

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