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Implant design and intraosseous stability of immediately placed implants: a human cadaver study

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Key words: immediate placement, implant design, implant diameter, installation torque, mandible, removal torque, resonance frequency analysis

Abstract

Objective: The objective of this study was to explore effects of implant macrodesign and diameter on initial intraosseous stability and interface mechanical properties of immediately placed implants.

Material and method: Mandibular premolars of four fresh-frozen human cadavers were extracted. Ø 4.1/4.8 mm ITI® TE®, Ø 4.1 and 4.8 mm solid screw synOcta® ITI® implants were placed into freshly prepared extraction sockets. Resonance frequency analysis was conducted to quantify primary implant stability quotient (ISQ). Installation torque value (ITV) and removal torque value (RTV) of the implants were measured using a custom-made strain-gauged torque wrench connected to a data acquisition system at a sample rate of 10,000 Hz. The vertical defect depth around the collar of each implant was measured directly by an endodontic spreader. The bone–implant contact was determined in digitalized images of periapical radiographs and expressed as percentage bone contact.

Results: The ISQ values of the TE® implant was higher than the Ø 4.1 mm implant ($P<0.01$), and comparable with the Ø 4.8 mm implants ($P>0.05$). ITVs and RTVs of TE® and Ø 4.8 mm implants were higher than the Ø 4.1 mm implant, although the differences between groups were statistically insignificant ($P>0.05$). The vertical defect depths around all types of implants were similar. In the radiographic analyses, percentage bone–implant contact of the TE® and Ø 4.8 mm implants were comparable at the marginal bone region and both were higher than that of the Ø 4.1 mm ITI® implant. Nonparametric correlations between groups revealed a significant correlation between ITV and RTV ($r=0.838$; $P<0.001$), but not between ISQ values and ITVs and RTVs ($P>0.05$).

Conclusion: Immediately placed ITI® TE® implant leads to initial intraosseous stability and interface mechanical properties comparable with a wide diameter implant.

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Owing to increasing clinical applications of immediate loading of implants in more demanding cases (Glauser et al. 2003; Lorenzoni et al. 2003) and immediate placement of implants into fresh extraction sockets (Balshi & Wolfinger 2002; Cooper et al. 2002; Nemcovsky et al. 2002), there is a growing need to unravel the cascade of biological events, bone apposition (Marcaccini et al. 2003; Nkenke et al. 2003) and mechanobiology of bone surrounding such implants (Geris et al. 2003; Jaecques et al. 2004). In essence, one of the most critical elements cultivating a safe mechanical environment for uneventful bone tissue differentiation around an immediately loaded implant is a stiff bone–implant interface, allowing low implant micromovement in bone (Pilliar et al. 1986; Kenwright et al. 1991; Szmukler-Moncler et al. 1998). When considering immediate loading for immediately placed implants, the mechanical properties of the interface is of utmost importance, as there is always an initial bone defect at the marginal region (Nemcovsky et al. 2002; Schropp et al. 2003). Inevitably, this bone defect increases the crown/implant ratio and theoretically leads to higher bending moments acting upon the implant. Therefore, immediate loading for immediately placed implants has been considered for splinted implants so far (Balshi & Wolfinger 2002; Cooper et al. 2002). Nowadays, however, design considerations for implants are progressively more embracing the anatomical and biomechanical needs for immediate placement by resembling natural roots more than ever. Because scientifically consistent evidence from animal experimental studies and epidemiological facts from human studies are scarce, the efficacy of immediately placed and loaded implants is yet unknown, but it is an undisputed fact that, the *a priori* for these implants must be high initial intraosseous stability.

So far, two remarkable attempts have been made to quantify intraosseous implant stability by vibration analysis; namely, transient excitation and continuous excitation (Huang et al. 2000). The Periotest Instrument (Siemens, Bensheim, Germany), based principally on transient excitation was designed originally to assess damping characteristics of natural teeth, but then has been extensively used for determining implant stability (Buser et al. 1990; Naert et al. 1995; Naert et al. 1998; Lorenzoni et al. 2003). However, Periotest values represent only a narrow range over the scale of the instrument and thus, provide insensitive information regarding implant stability (Olive & Aparcio 1990). Further, the technique does not mirror the mechanical properties of the interface (Cehreli et al. 2004) and therefore, its merit on detection of osseointegration is a matter of debate. The latter method, resonance frequency analysis (RFA), based on continual excitation of the implant through dynamic vibration analysis makes use of a transducer connected to an implant, which is excited over a range of sound frequencies with subsequent measurement of vibratory oscillation of the implant. This noninvasive technique seems to provide relatively more sensitive information (implant stability quotient (ISQ) on a scale from 1 to 100) in comparison with the Periotest values and therefore, getting more popular as a diagnostic tool lately (Meredith et al. 1996, 1997; Sul et al. 2002; Nkenke et al. 2003).

Recent studies show that implant design has a great impact on initial stability in bone (Meredith 1998; O'Sullivan et al. 2000; Sul et al. 2002). In order to provide a scientific basis for clinical applications of immediate placement coupled with immediate loading, the purpose of this study was to explore the initial intraosseous stability as well as mechanical properties of the bone–implant interface of the ITI® TE® implant (Straumann Institute, Waldenburg, Switzerland), designed specifically for immediate placement and compare its properties with conventional synOcta® solid screw ITI® implants (Straumann Institute). Because the best experimental model representing biomechanical characterization of alveolar bone is humans, the study was undertaken on fresh cadavers. It was surmised that the ITI® TE® implant (neck Ø 4.8 mm; body Ø 4.1 mm), having an increased surface area regarding the tapered/cylindrical implant profile, and congruent bone–implant contact with reduced thread pitch configuration leading to minimalization of the horizontal defect dimension, would have higher ISQ values than a Ø 4.1 mm solid screw ITI® implant, but comparable with a Ø 4.8 mm implant. Further, it was hypothesized that, the increased number of threads coupled with their design would substantially increase the mechanical properties of the bone–TE® implant interface.

Material and methods

Human cadavers

The experiments were undertaken in four fresh frozen human cadavers (one woman and three men), who had bequeathed their bodies to Department of Anatomy, Faculty of Medicine, University of Ankara for medical–scientific research purposes. The reasons of death were traffic accidents for three subjects and heart attack for one man. The ages at death were 32 years for the woman and 37, 47, and 68 years for the men. Prior to experiments, the frozen cadavers were left in room temperature for 48 h to eliminate possible effects of frozen bone on measurement of installation torque value (ITV), removal torque value (RTV) and ISQ values.

Implants and surgical procedures

In this study, ITI® TE® (body Ø 4.1 mm; neck Ø 4.8 mm), Ø 4.1 and 4.8 mm synOcta® solid screw esthetic plus ITI® dental implants (Straumann Institute), all having 12 mm length were used (Fig. 1). In three cadavers, full-thickness flaps were reflected and bilateral mandibular first and second premolars were extracted by an experienced oral surgeon with extensive care taken as to not to expand the bone sockets. In one cadaver (male, age: 68 years), the right second premolar was missing and therefore, full-thickness flaps around bilateral mandibular first premolars were reflected, the teeth were extracted and sockets used for the experiments. The sockets ($n = 14$) were randomly divided into three equal groups for placement of three types of implants, resulting in seven sites for TE® and Ø 4.1/4.8 mm solid implants. The implant sockets for placement of TE® implants (Straumann Institute) were prepared using Ø 2.2 and 2.8 mm pilot and Ø 3.5 mm twist drills under copious saline irrigation. Then, TE® implants were placed into the sockets approximately 0.5 mm apically to the cemento-enamel junction of neigboring tooth, used as a reference (Buser & von Arx 2000). The rationale behind this application employed for all types of implants was to quantify the final ITV by a custom-made manual torque device (Fig. 2). The Ø 4.1 and 4.8 mm synOcta® solid screw implants (Straumann Institute) were placed consecutively in the same

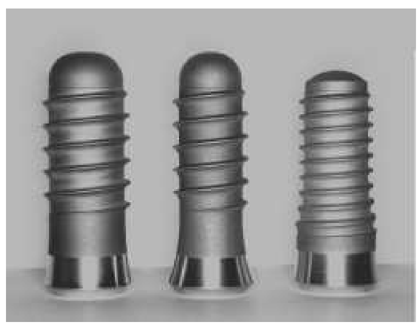

Fig. 1. From left to right Ø 4.8 and 4.1 mm standard solid screw, and TE® implants.

extraction sockets. First, the Ø 4.1 mm solid screw ITI® implant was installed, the measurements were undertaken and upon removal of the implant, the socket was enlarged by a Ø 4.2 mm surgical drill for placement of the upcoming Ø 4.8 mm solid screw ITI® implant. Because the diameter of the last surgical drill was wider than the Ø 4.1 mm implant, the procedure resulted in a fresh bone socket for placement of the Ø 4.8 mm implant. Taking the thread design of the ITI implant and the diameter of the last surgical drill into account, the trabecular bone surrounding the threads and the Ø 4.1 mm implant was removed before placement of the Ø 4.8 mm implant. Even if there were broken or damaged trabeculae in the vicinity of the Ø 4.1 mm implant, they were either removed by the last surgical drill or compressed together with the surrounding bone during installation of the Ø 4.8 mm implant into the fresh Ø 4.2 mm socket. Therefore, the procedure had negligible or no effect on primary implant stability of Ø 4.8 mm implant.

Quantification of ITV, vertical defect depth and radiographic evaluation

All implants were subjected to quantification of ITV. A custom-made manual torque device equipped with strain gauges was used. The technical details of the torque device and calibration experiments are explained elsewhere (Cehreli et al. 2004). In brief, the strain-gauge signals during torque tightening of the implant were delivered to a data acquisition system (ESAM Traveller 1, Vishay Micromeasurements Group, Raleigh NC, USA) and were displayed in a computer by a special software (ESAM; ESA Messtechnik GmbH, Olching, Germany) at a sample rate of 10,000 Hz. Then, the strain data were converted to torque units (N cm) using the general formula

$$\text{Torque} = K \times \varepsilon$$

where K is the calibration constant and ε is the strain-gauge reading. For quantification of ITV, the custom-made torque device was connected to the adapter for ratchet (046.462; Straumann Institute), which was mounted to the premounted transfer part of the implant (Fig. 2). The measurements were undertaken when the implant was placed into final position by an approximately half-turn of the torque device to clockwise direction.

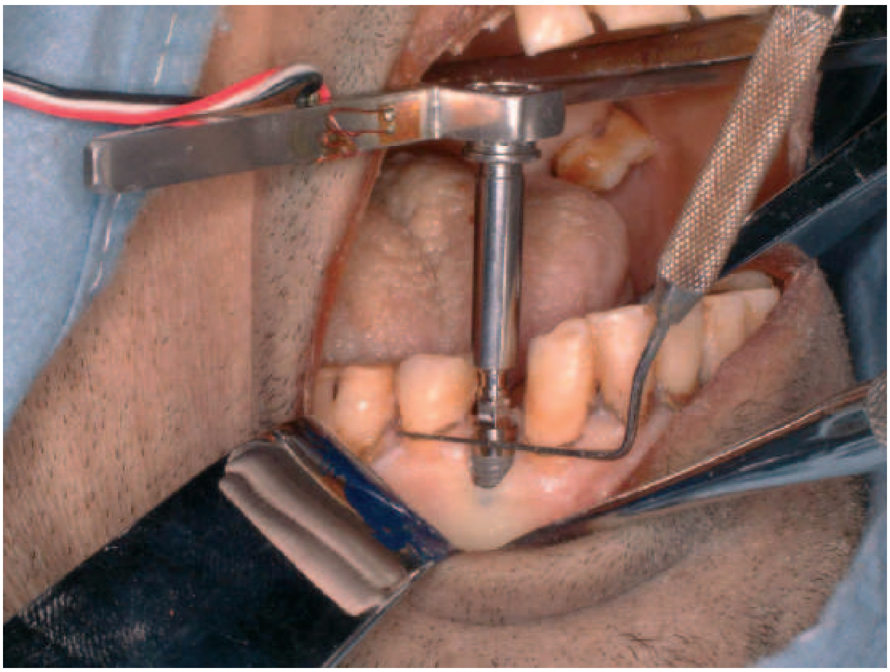

Fig. 2. The TE® implant installed into final position by the custom-made manual torque wrench. Note that the collar of the implant is located at the cemento-enamel junction of neighboring teeth.

Upon placement of each implant, the vertical defect depths at four sites (mesial, distal, buccal and lingual) were measured by an endodontic spreader (Schwert 3620/04, Tuttlingen, Germany) with a stopper. For all measurements, the coronal reference point was the superior horizontal level of the transmucosal part of the implants. The distance from the reference point to the base of the defect, as determined by the stopper to the tip of the spreader was measured by a digital caliper (Fowler-Sylvac, Sylvac SA, Crissier, Switzerland). Then, standard periapical radiographs were obtained from all implants by the parallel technique (Goaz & White 1994) (Fig. 3). 70 kVp, 10 mA and 0.42 s were used as exposure parameters and the radiographs were processed in an automatic processor (Dürr Dental XR – 24-II; Dürr Dental GmbH & Co. KG, Bissingen, Germany). The radiographs were scanned and high-resolution digital images were

Fig. 3. Periapical radiographs of freshly placed implants. From left to right TE® (a) Ø 4.1 mm (b) and Ø 4.8 mm (c) standard solid screw ITI® implants.

transferred into a computer software program. Under magnification (300%), the entire bone–implant contact of the implants was determined using the threads as a reference, and expressed as percentage bone contact.

Resonance frequency and removal torque analyses

The RFA was undertaken upon removal of the premounted transfer part from each implant and using the Osstell® instrument (Integration Diagnostics, Gothenburg, Sweden). The transducer (F4 L8.5, Integration Diagnositcs) was connected manually to the implant orthoradially with the upright part on the oral side (Fig. 4). The RFA transducer has been designed as an offset cantilever beam with an attached piezoceramic element. The excitation signal is a 5–15 Hz sine wave with a peak amplitude of 1 V (Meredith 1998). RFA was undertaken two times for each implant to ascertain reiteration. Then, the RTV of the implant was measured using the torque device and equipment used for ITV, and during a half-turn of the implant to counterclockwise direction.

Statistical analysis

The means of ISQ values, ITVs, and RTVs of three type of implants were compared by Friedman tests at 95% confidence level. In order to determine whether a statistically significant correlation could be established between RFA, ITV, and RTV, Spearman's rho was determined for each combination: RFA and ITV, RFA and RTV, and ITV and RTV.

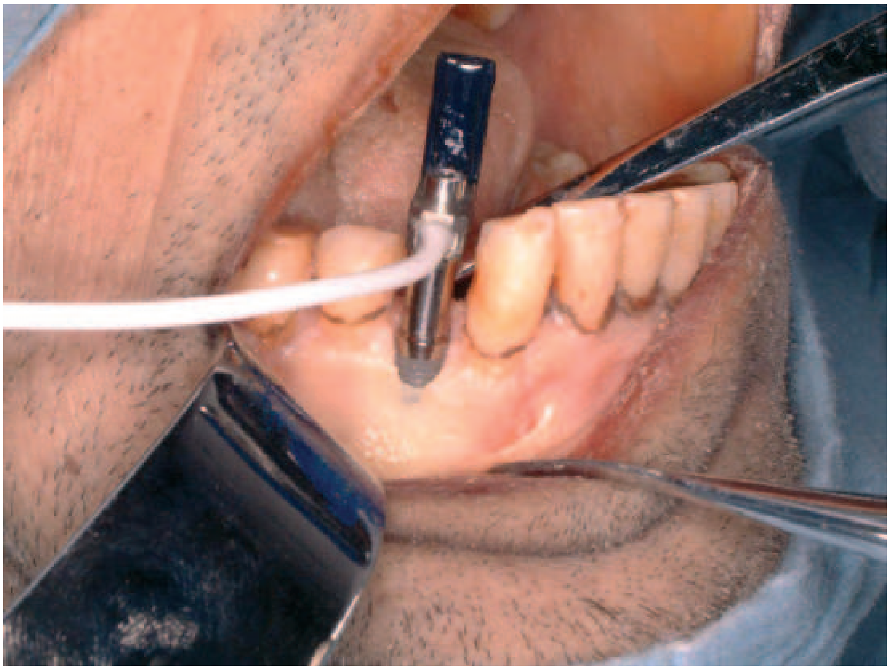

Fig. 4. Resonance frequency transducer connected to the TE® implant upon removal of the premounted transfer part of the implant.

Table 1. **ISQ values, ITVs, and RTVs of the implants tested**

	TE® implant	Ø 4.1 mm solid screw implant	Ø 4.8 mm solid screw implant
ISQ	68	56	69
	68	60	63
	73	55	67
	73	59	64
	64	52	65
	67	58	62
	72	64	66
Mean ± SEM	69.28 ± 1.30	57.71 ± 1.45	65.14 ± 0.91
ITV (N cm)	51.83	40.28	67.12
	89.75	46.16	139.16
	111.70	89.00	109.87
	32.33	45.75	47.62
	178.87	119.37	134.25
	91.25	36.00	75.75
	94.12	94.50	149.37
Mean ± SEM	92.83 ± 17.67	67.29 ± 12.48	103.30 ± 15.10
RTV (N cm)	103.62	20.16	50.70
	76.91	43.47	116.58
	114.75	84.25	94.62
	34.20	41.50	35.37
	170.25	56.87	85.25
	80.12	25.62	39.62
	103.12	84.25	109.25
Mean ± SEM	97.56 ± 15.72	50.87 ± 9.74	75.91 ± 12.72

ISQ, input stability quotient; ITV, Installation torque value; RTV, removal torque value.

Results

The ISQ values, ITVs, and RTVs of three types of implants are presented in Table 1. The mean rank of ISQ values of the TE® implant (2.71) was higher than that of the Ø 4.1 mm ITI® implant (1.00) ($P<0.01$), and comparable with the Ø 4.8 mm (2.29) implants ($P>0.05$). The mean rank of ISQ values of the Ø 4.1 mm solid screw implant was significantly lower than the Ø 4.8 mm ITI® implant ($P<0.05$). The mean rank of ITVs of TE® implant (2.14) and Ø 4.8 mm ITI® implant (2.57) were higher than the Ø 4.1 mm ITI® implant (1.29), although the differences between groups were statistically insignificant ($P>0.05$). Likewise, the mean rank of RTVs of TE® implant (2.43) and Ø 4.8 mm ITI® implant (2.29) were higher than the Ø 4.1 mm ITI® implant (1.29), but the differences between groups were statistically insignificant ($P>0.05$).

Vertical defect depths at four target sites are presented for all types of implants in Table 2, as mean and standard deviation. For all implants, vertical defect dimensions at the buccal and lingual sides were higher than those measured at the approximal sides. There was a correlation between radiographically determined bone levels and probed bone levels at the mesio-distal sides. The percentage bone–implant contact of the TE® implant, as determined by radiographic evaluation, was comparable with the Ø 4.8 mm ITI® implant at mesial and distal regions and both were higher than that of the Ø 4.1 mm ITI® implant (Table 3). Nonparametric correlations between groups revealed a significant correlation only between ITV and RTV ($r=0.838$; $P<0.001$). The correlation between ITV and RTV was significant for the TE® implant ($r=0.786$; $P<0.05$), Ø 4.1 mm implant ($r=0.847$; $P<0.05$) and the Ø 4.8 mm implant ($r=0.833$; $P<0.01$). A statistically significant correlation could not be detected between ISQ values with ITV and RTV ($P>0.05$).

Discussion

It is a well-known fact that primary stability of implants depends on surgical techniques employed, bone density and implant design, particularly the length and diameter of implants (Meredith 1998; Barewal et al. 2003). Because the length of all implants was same (12 mm), the results of the present study also confirm that implant diameter has a decisive role on initial intraosseous stability of immediately placed implants. The TE® implant, designed originally for immediate placement has a tapered/cylindrical form, which is a combination of Ø 4.1 and 4.8 mm solid screw implants. The increased diameter at the collar region coupled with more threads lead to more bone contact and enhanced stability (17%) in comparison with a Ø 4.1 mm solid screw ITI® implant. However, the macrodesign of the TE® implant does not seem to be extremely advantageous over the Ø 4.8 mm solid screw ITI® implant in terms of primary intraosseous stability, as the ISQ values were almost same. Nevertheless, the TE® implant has an undisputed clinical advantage over the Ø 4.8 mm solid screw ITI® implant, as it can be placed in all regions where placement of a regular-diameter implant is planned and without any risks of damaging roots of neighboring teeth. With the use of this implant, there is also a possibility of decreasing the horizontal defect dimension between the implant and bone, although complete elimination of the vertical/horizontal alveolus defect buccolingually appears impossible for all type of implants tested. Indeed, there is always a site-specific deep bone defect around an immediately placed implant, which depends on the cross-sectional shape of the root(s). In this study, therefore, the deepest defects were located at the buccal and lingual aspects of the implant. Another possible clinical advantage of the TE® implant is the decreased thread pitch distance

***Table 2*. Vertical defect depths (mm) at four sites (mesial, distal, buccal, and lingual) around three types of implants**

	Mesial	Distal	Buccal	Lingual
TE® implant	0.6	0.81	7	12.47
	2.2	2.9	11.17	3.02
	2.04	1.75	8.29	6.25
	1.33	1.17	12.71	4.92
	2.51	2.41	7.65	5.91
	1.29	1.56	7.07	6.67
	0.94	1.85	4.63	1.71
Mean (standard deviation)	1.55 (0.70)	1.77 (0.70)	8.36 (2.73)	5.85 (3.43)
Ø 4.1 mm solid screw implant	0.54	0.35	1.09	8.93
	2.98	3.71	10.26	5.53
	3.02	2.67	12.94	8.06
	5	2.27	5.9	6.99
	5.8	4.8	7.91	0.78
	1.74	0.94	12.06	6.5
	3.71	2.14	4.81	1.54
Mean (standard deviation)	3.25 (1.80)	2.41 (1.52)	7.85 (4.24)	5.47 (3.14)
Ø 4.8 mm solid screw implant	0.72	1.87	0.95	6.05
	2.47	3.14	7.67	5.13
	1.94	1.79	14.82	7.41
	1.76	1.88	4.74	6.82
	1.28	0.95	5.69	1.6
	0.68	1.11	10.81	5.55
	1.57	1.56	3.37	3.05
Mean (standard deviation)	1.48 (0.65)	1.75 (0.71)	6.86 (4.70)	5.08 (2.07)

***Table 3*. Percentage bone–implant contact for three types of implants at mesial (M) and distal (D) regions, as determined by radiographic evaluation**

	TE (M)	Ø 4.1 (M)	Ø 4.8 (M)	TE (D)	Ø 4.1 (D)	Ø 4.8 (D)
Tip of 1st thread	43	–	–	57	–	–
Tip of 2nd thread	86	14	57	71	57	100
Tip of 3rd thread	100	–	–	86	–	–
Tip of 4th thread	100	43	100	86	86	100
Tip of 5th thread	71	–	–	86	–	–
Tip of 6th thread	100	57	100	100	86	100
Between 1st and 2nd threads	0	–	–	0	–	–
Between 2nd and 3rd threads	0	14	29	14	43	57
Between 3rd and 4th threads	57	–	–	29	–	–
Between 4th and 5th threads	43	29	71	57	57	57
Between 5th and 6th threads	100	–	–	86	–	–

The percentage bone contact is presented taking the number of threads ($n=6$) of the TE as a reference. The threads of Ø 4.1 and 4.8 mm solid screw implants correspond to 2nd, 4th, and 6th threads of the TE.
TE: TE® implant; Ø 4.1: Ø 4.1 mm solid screw ITI® implant; Ø 4.8: Ø 4.8 mm solid screw ITI® implant.

(0.8 mm) and increased number of threads, which may lead to decreased levels of micromovement in bone. We should, however, note that this issue has not been explored herein, and remains as an open topic for investigation. Clearly, the increased number of threads of the TE® implant improved mechanical properties of the interface; there was a decrease in RTVs of the Ø 4.8 mm (27%) and Ø 4.1 mm (25%) solid screw ITI® implants, but it was almost constant (1.05% increase) for TE® implants. The increased number of threads of the TE® implant led to higher surface area and friction along the interface during implant removal. Therefore, the RTVs of the TE® implants were higher than those of the Ø 4.8 mm implant, although their ITVs were lower. Notably, the increased number and design of the threads of the TE® implant may therefore be more favorable than that of the 4.8 mm implant in terms of providing a safe mechanical environment for the healing interface of loaded single-tooth immediate implants, as the biomechanical effects of torsional forces are more intense on single-tooth restorations in comparison with multi implant-supported fixed prostheses.

The ITVs and RTVs of the TE® and Ø 4.8 mm implants were higher than the Ø 4.1 mm solid screw ITI® implant, although a statistically significant result was not obtained. This was related to the increased surface arising from tapered/cylindrical design of the TE® implant. Hence, it seems that regardless of the diameter at the middle and apical parts of the body, implants having a wider neck, i.e., Ø 4.8 mm than a regular-diameter implant (Ø 4.1 mm) will lead to ISQ values similar to a wide implant (Ø 4.8 mm). This implies that ISQ values do not mirror the bone–implant contact at deeper parts, but rather at the marginal bone region. Although the displacement of the cantilever beam of the transducer is less than 1 μm, the ISQ values may also present false-positive results in different cases, i.e., a regular diameter implant having bone contact at the marginal region may lead to higher ISQ values than a wide implant without any bone contact at the collar region. Therefore, the clinical value of RFA may be questionable in some certain cases, although its merit on detection of implant stability during osseous healing is valid (Meredith et al. 1997; Meredith 1998).

Recent histomorphometric studies did not reach a consensus on a possible correlation between ISQ values and levels of implant–bone contact (Rasmusson et al. 1999; Nkenke et al. 2003). The radiographic evaluation of this study suggests that bone contact, particularly at the marginal region has a decisive role on the ISQ value. If an intimate bone–implant contact is achieved at the collar region, the ISQ value increases. Because the horizontal alveolus defect distance (jumping distance) between a Ø 4.1 mm solid screw ITI® implant and marginal bone is relatively high, a stiff and intimate bone contact is frequently achieved more apically, which leads to lower ISQ values and interface mechanical properties, as determined by ITV and RTV. In contrast, the horizontal defect distance will decrease in the event a Ø 4.8 mm solid screw or a TE® implant is placed, and eventually interface mechanical properties will increase. It should, however, be taken into account that the clinical value of radiographic analysis is also a matter of debate. First, periapical radiographs can never provide ultra-high resolution images to determine exact bone–implant contact and frequently will lead to superimposed images. In addition, the site-specific characterization of the bone defects resulting from especially buccolingual dissimilarity between the rotational symmetric design of a dental implant, when compared with the elliptical nature of tooth root in horizontal plane, is mostly concealed in the images, as seen in the present study, and may lead to false interpretations. Therefore, direct measurement of the bone defects will be more reliable than radiographic evaluation, although such measurements cannot be performed during the tissue-healing phase. However, such measurements also do not reveal where a stiff and intimate bone contact is achieved. As observed in the present study, the vertical defect dimensions at four sites of all implants were similar, but the ISQ values of TE® and Ø 4.8 mm implants were higher than the Ø 4.1 mm implant.

In the present study, a statistically significant correlation could not be established between ISQ values and ITVs and RTVs. This was probably a consequence of the small sample size (seven sites for each implant type) used. In essence, the rationale behind this approach was to explore whether ISQ values express the mechanical properties of the interface. Nevertheless, it seems that when the ISQ values are high, there is a possibility that the implant may be tightened with higher torque values, as the ISQ, ITVs and RTVs of TE® and Ø 4.8 mm implants were higher than the Ø 4.1 mm solid screw ITI® implant. Yet, more fundamental studies are required to elucidate a possible correlation between ISQ values and interface mechanical properties.

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Résumé

Le but de cette étude a été d'explorer les effets du modèle macroscopique et du diamètre sur la stabilité intraosseuse primaire et les propriétés mécaniques interface des implants placés immédiatement. Les prémolaires mandibulaires de quatre cadavres humains juste congelés ont été avulsées. Les implants ITI®synOcta® en vis solide d'un diamètre de 4,1 mm et 4,8 mm, et des ITI®TE® d'un diamètre de 4,1/4,8 mm ont été placés dans les alvéoles d'extractions fraîchement préparées. L'analyse par fréquence de résonnance a été effectuée afin de quantifier la stabilité primaire de l'implant (ISQ). Les valeurs d'insertion à l'installation (ITV) et de torsion d'enlèvement (RTV) des implants ont été mesurées en utilisant une jauge de force de moment connectées à un système d'acquisition des données à un taux d'échantillonnage de 10,000 Hz. La profondeur de la lésion verticale autour du collet de chaque implant a été mesurée directement par une sonde endodontique. Le contact os-implant a été déterminé via les images digitalisées de radiographies périapicales et exprimé en pourcentage de contact osseux. Les valeurs ISQ de l'implant TE® étaient plus importantes que celles de l'implant d'un diamètre de 4,1 mm ($P<0,01$), et comparables aux implants d'un diamètre de 4,8 mm ($P>0,05$). Les valeurs ITV et RTV pour les implants TE® et d'un diamètre de 4,8 mm étaient supérieures à celles des implants de 4,1 mm bien que les différences entre les groupes n'étaient pas significatives ($P>0,05$). Les profondeurs des lésions verticales autour de tous les implants étaient semblables. Dans les analyses radiographiques le pourcentage de contact os-implant des implants TE® et ceux d'un diamètre de 4,8 mm étaient comparables dans la région osseuse marginale et les deux étaient supérieurs à celui recontré avec les implants d'un diamètre de 4,1 mm. Les corrélations non-paramétriques entre les groupes ont révélé une corrélation significative entre ITV et RTV ($r = 0{,}838$; $P < 0{,}001$) mais pas entre les valeurs ISQ et ITV et RTV ($P > 0{,}05$). Les implants ITI® TE® placés immédiatement apportent une stabilité intraosseuse initiale et des propriétés mécaniques d'interface comparables à celles d'un implant large.

Zusammenfassung

Implantatgestaltung und intraossäre Stabilität von Sofortimplantaten: Eine Studie an menschlichen Präparaten

Ziele: Das Ziel dieser Studie war, den Effekt der Makroform von Implantaten und des Durchmessers auf die initiale intraossäre Stabilität und die mechanischen Eigenschaften an der Berührungsfläche bei Sofortimplantaten zu untersuchen.
Material und Methoden: Bei vier frisch eingefrorenen menschlichen Kadavern wurden die Prämolaren im Unterkiefer extrahiert. In die frisch präparierten Extraktionsalveolen wurden ITI® TE® Ø 4.1/4.8 mm und SynOcta® Vollschraubenimplantate Ø 4.1 und 4.8 mm eingesetzt. Zur Quantifizierung der Implantatstabilität wurde eine Analyse der Resonanzfrequenz (ISQ) durchgeführt. Die Eindrehmomente (ITV) und die Ausdrehmomente (RTV) der Implantate wurden mit einem individuell angefertigten Drehmomentschlüssel mit Dehnmessstreifen gemessen. Der Schlüssel war mit einem System zur Datenerhebung mit einer Aufnahmerate von 10,000 Hz verbunden. Die vertikale Defekttiefe um den Hals jedes Implantats wurde direkt mit einem endodontischen Spreader gemessen. Der Knochen-Implantat-Kontakt wurde auf digitalisierten Bildern von periapikalen Röntgenaufnahmen bestimmt und als Prozent Knochenkontakt ausgedrückt.
Resultate: Die ISQ Werte des TE® Implantats waren höher als beim Ø 4.1 mm Implantat ($P < 0.01$) und vergleichbar mit den Werten der Ø 4.8 mm Implantate ($P > 0.05$). ITV und RTV der TE® und Ø 4.8 mm Implantate waren höher als bei den Ø 4.1 mm Implantaten, jedoch waren die Unterschiede zwischen den Gruppen statistisch nicht signifikant ($P > 0.05$). Die vertikalen Defekttiefen waren um alle Implantattypen ähnlich. In der radiologischen Analyse waren die Prozent Knochen-Implantat-Kontakt der TE® und Ø 4.8 mm Implantate in der marginalen Knochenregion vergleichbar und beide waren höher als bei den Ø 4.1 mm ITI® Implantaten. Nichtparametrische Korrelationen zwischen den Gruppen zeigten eine signifikante Korrelation zwischen ITV und RTV ($r = 0.838$; $P < 0.001$), aber nicht zwischen den ISQ Werten und ITV und RTV ($P > 0.05$).
Schlussfolgerung: Sofort gesetzte ITI® TE® Implantate führen zu einer initialen intraossären Stabilität und mechanischen Eigenschaften an der Berührungsfläche, welche mit der Stabilität und den Eigenschaften von Implantaten mit grossem Durchmesser vergleichbar sind.

Resumen

Propósito: El objetivo de este estudio fue explorar los efectos del macrodiseño y el diámetro de los implantes en la estabilidad inicial intraósea y las propiedades mecánicas de la interfase de los implantes colocados inmediatamente.
Material y Métodos: Se extrajeron los premolares mandibulares de cuatro cadáveres frescos congelados. Se colocaron implantes macizos ITI® TE® Ø 4.1/4.8 mm, synOcta® ITI® Ø 4.1 y 4.8 mm en huecos frescos de extracción preparados. Se llevó a cabo análisis de frecuencia de resonancia para cuantificar la estabilidad primaria del implante (ISQ). Se midió el valor del torque de instalación (ITV) y el valor del torque de remoción (RTV) de los implantes usando un calibrador de strain de torque de chicharra hecho a medida conectado a un sistema de adquisición de datos a un índice de muestreo de 10,000 Hz. La profundidad del defecto vertical alrededor del cuello de cada implante se midió directamente con un ensanchador de endodoncia. El contacto hueso implante se determinó en imágenes digitalizadas de radiografías periapicales y expresadas como porcentaje de contacto óseo.
Resultados: Los valores ISQ del implante TE® fueron mayores que los del implante Ø 4.1 ($P < 0.01$), y comparables con los de los implantes de Ø 4.8 ($P < 0.05$). Los ITV y los RTV de los TE® y los implantes Ø 4.8 fueron mayores que los del implante de Ø 4.1, aunque las diferencias entre los grupos fueron estadísticamente insignificantes ($P > 0.05$). Los defectos verticales alrededor de todos los tipos de implantes fueron similares. En los análisis radiográficos, el porcentaje de contacto hueso-implante de los implantes TE® y de Ø 4.8 fueron comparables en la región marginal y ambos fueron mayores que aquellos del implante ITI® de Ø 4.1. Las correlaciones no paramétricas entre grupos revelaron una significativa correlación entre ITV y RTV ($r = 0.838$); ($P < 0.001$), pero no entre los valores ISQ e ITV y RTV ($P > 0.05$).
Conclusión: Los implantes ITI® TE® inmediatamente colocados conducen a una estabilidad intraósea inicial y a unas propiedades mecánicas de la interfase comparables con un implante de diámetro ancho.

要旨

目的：本研究の目的は、インプラントのマクロ・デザインと直径が即時埋入インプラントの骨内の初期安定性と界面の力学的特性に及ぼす影響を調べることであった。
材料と方法：４人の新鮮凍結ヒト献体の下顎小臼歯を抜去し、４．１ｍｍ径/４．８ｍｍ長のITI®TE®と４．１ｍｍ径/４．８ｍｍ長の充実型スクリュー･インプラント synOcta® ITI®を新鮮抜歯窩に埋入した。共鳴周波数分析を行い、インプラントの初期安定性（ＩＳＱ）を定量化した。インプラントの埋入トルク値（ＩＴＶ）と抜去トルク値（ＲＴＶ）を特注の歪ゲージ付きトルク・レンチを用い、データ取得システムに連結して１０、０００Ｈｚのサンプル速度で測定した。各インプラント頚部周囲の欠損の垂直的深さは歯内療法用スプレッダーを用いて直接計測した。骨とインプラントの接触面積はペリアピカルＸ線のデジタル画像において計測し、骨接触面の比率として表した。
結果：TE®インプラントのＩＳＱ値は４．１ｍｍ径インプラントより大きく（ｐ＜０．０１)、４．８ｍｍ径インプラントの値に相当した（ｐ＞０．０５)。TE®及び４．８ｍｍ径インプラントのＩＴＶとＲＴＶは４．１ｍｍ径インプラントよりも大きかったが、グループ間の差異は統計学的に有意ではなかった（ｐ＞０．０５)。全てのタイプのインプラント周囲の欠損の垂直的深さは類似していた。レントゲン像の分析において、TE®と４．８ｍｍ径インプラントの骨･インプラントの接触面積の比率は、辺縁骨の領域では類似しており、両方とも４.１ｍｍ径のITI®インプラントより高い値であった。グループ間のノンパラメトリックな比較では、ＩＴＶとＲＴＶの間に統計学的な有意差が示されたが（Ｒ＝０．８３８；Ｐ＜０．００１)、ＩＳＱ値とＩＴＶ及びＲＴＶの間には相関性はなかった（ｐ＞０．０５)。
結論：即時埋入 ITI® TE®インプラントは、骨内初期安定性と、径の太いインプラントに匹敵する界面の力学的特性をもたらすものである。
キーワード：インプラント・デザイン、インプラント径、共鳴周波数分析、埋入トルク、抜去トルク、下顎、即時埋入

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