

The initial stability of dental implant with horizontal plate (An in vitro study)

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ABSTRACT

Background: The Initial (primary) stability is one of the factors that play an important role in the success of the dental implants. The purpose of this study was to evaluate the initial stability of dental implant with horizontal plate by using five analytical tests: insertion torque, removal torque, resonance frequency analysis, push-in test and pull-out test.

Materials and methods: Two different lengths of dental implants (5mm and 10mm) were tested in this study; each dental implant was 4mm in diameter with a square threads shape of 1mm pitch and 0.5mm depth. The crestal area was 4.2mm diameter contained a right angle margin circumferential ring while the apical area was tapered with two self-tapping grooves. In this study, the initial stability of dental implants' design was compared with initial stability of dental implants of the same dimensions and design that engage horizontal plates of 1.5mm thickness at the apical part. All dental implants were implanted into a solid rigid polyurethane foam blocks (artificial bone) of 0.48g/cm³ density and tested by the five initial stability tests. Each test was done with forty samples (twenty samples of 5mm length and twenty samples of 10mm length).

Results: The statistical analysis was performed and the result showed that there was very highly significant difference between dental implants with the horizontal plates and dental implants without the horizontal plates of both 5mm and 10 mm lengths in four initial stability tests which were insertion torque, removal torque, push-in test and pull-out test. The statistical analysis of the resonance frequency analysis showed that there was non-significant difference between dental implants with the horizontal plates and dental implants without the horizontal plates of both lengths.

Conclusion: These results implied that the dental implants with the horizontal plates had better primary stability compared with the dental implants without the horizontal plates confirming that the horizontal plates enhanced the primary stability of the dental implants.

Key words: Initial stability, dental implant, horizontal plate. (J Bagh Coll Dentistry 2014; 26(4):95-101).

INTRODUCTION

Despite the progress in the materials and designs of dental implants, the potential for clinical failure is a significant concern for both dentists and patients. The initial stability is an important factor affecting the success rate of implant treatments ⁽¹⁾. Initial (Primary) stability is the mechanical coherence between bone and dental implant fixture immediately after implantation. It is well known that primary stability plays an essential role in successful osseointegration ⁽²⁾.

The lack of primary stability had been assumed to be the causative factor for early implant failure ⁽³⁾. Achieving stability depends on the bone density, the surgical technique, and the microscopic and macroscopic morphology of the implant used ⁽⁴⁾. The final clinical success of oral implants is determined by various implant and non-implant related parameters. Implant-related parameters are implant shape, implant surface configuration and implant surface composition. Non-implant-related parameters are mainly dealing with the skills of the surgeon, health condition of the patient and final loading protocol of the implant supported prosthetic construction ⁽⁵⁾.

The solid rigid polyurethane foam blocks were widely used as an alternative for human jaw bones ⁽⁶⁾. In order to simulate jaw bone the density of the polyurethane block should be almost similar to the natural jaw bone density.

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MATERIALS AND METHODS

Cylindrical dental implants used in this study were mechanically machined from 4.2mm commercially pure Titanium rods by using lathe machine. Each implant had 4mm body diameter and 4.2mm crestal diameter, the shape of the threads were square with 1mm pitch and 0.5mm thread depth. The crest modules were 0.2mm wider than the body diameter and contained a circumferential ring with right angled margins followed by a crestal smooth 0.5mm length collar. The apical portion was tapered, flat ended and contained two self-tapping grooves ⁽⁷⁾. Two Lengths of dental implants were used in this study 10mm length and 5mm length (Fig.:1) both were compared with the same design and length of dental implants but with horizontal plates.

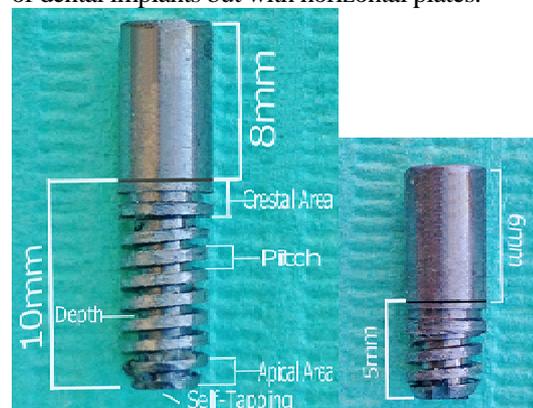


Fig. 1: Dental implants

The horizontal plates were made from commercially pure titanium disks. Each plate was 9mm length, 9mm width and 1.5mm thickness. The shape of the horizontal plate was square with one curve side; the other three sides contained inner slots for the mounting of the insertion guide. The plate had five holes one at the center with 4mm diameter and contained inner threads similar to the implant threads and the other four located at each corner of the plate with 1mm diameter⁽⁸⁾ (Fig.: 2). The horizontal plate engages the dental implant at the apical area (0.5 mm above the apical end).

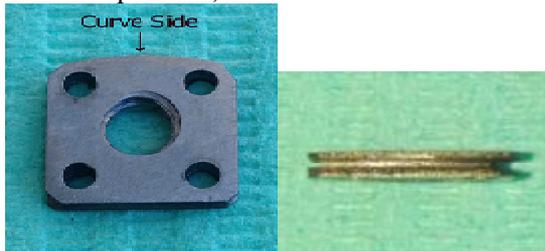


Fig. 2: The horizontal plate

Solid rigid Polyurethane foam blocks with a bone density of 0.48 g/cm^3 were chosen⁽⁹⁾. This type of artificial bone had definite mechanical properties of 18MPa compressive strength, 12MPa tensile strength and 7.6MPa shear strength⁽⁶⁾. The artificial bone specimens' dimensions that selected in this study were 3cm length, 4cm height and 1.1cm thickness.

Drilling Procedures

Each artificial bone block specimens were attached to the vice of the drilling engine stand (Fig.:3) (that help to standardize drilling angulation and depth of the implant site). The depth of the drilling was determined by the side gauge that present on the drilling engine stand. Implant site preparation was done at drilling speed of 2500 rpm⁽¹⁰⁾ with distilled water cooling by using disposable syringes.



Fig. 3: Drilling engine stand

For the dental implants without the horizontal plates, the drilling procedure was started by attaching the bone block to the vice of the drilling engine stand then the drilling started by using 2.8mm stainless-steel straight drill with distilled water cooling until it reach

5mm depth in case of 5mm dental implant and 10mm depth for 10mm dental implant. Then the drilling continued by gradually increasing the straight drills sizes (3.3mm then 3.8mm diameter)⁽⁷⁾, this procedure also done under distilled water cooling.

The drilling procedure for the dental implants (5mm) with the horizontal plates was started by attaching the bone block to the vice of the drilling engine stand and a 5mm dental implant drilling guide was held on the top of the block then the implant site preparation started with 2.8mm stainless-steel straight drill passing through the guide to a 5mm depth in the bone block (Fig.: 4) in the presence of a distilled water cooling.



Fig. 4: Drilling guide and 2.8mm drill

After that the drilling guide was fixed to the block by using a screw of 2.9mm diameter (Fig.:5) then with copious amount of water cooling the horizontal plate site preparation started by using 1.4mm thickness disk drill⁽⁸⁾ that run along the drilling guide's slot toward the bone block until 10mm (inside the bone) had been reached (until the sliding area touched the bone block) (Fig.: 6). The drilling guide could be replaced by a stereolithographic surgical template.

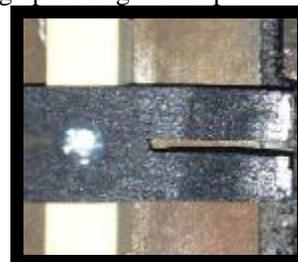


Fig. 5: Drilling guide fixed by screw

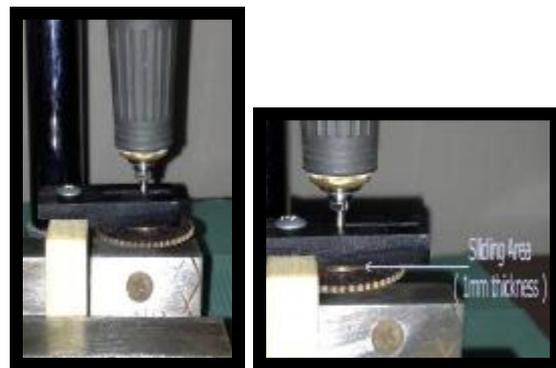


Fig. 6: Horizontal plate site preparation

After horizontal plate site preparation was done the drilling guide should be removed and under distilled water cooling a sequence of gradual straight drills must be used to finish the 5mm implant site preparation. The position of the horizontal plate determined by the drilling guide and the thickness of the sliding area (1mm) and it was 3mm from the top of the bone in case of the 5mm dental implant.



Fig. 7: Bone block after preparation

Same steps was followed to the 10mm dental implant with horizontal plate site preparation but with only one difference by changing the horizontal plate drilling guide that leaving the horizontal plate in a position of 8mm from the top of the artificial bone block.

Implants Placement and Insertion Torque Measurements:

Dental implant insertion was done by using manual torque meter (Fig.: 8) to measure the maximum torque that was required for complete fixture insertion. For the dental implants without horizontal plate, the fixtures were inserted into the prepared sites and the torque meter's maximum readings were recorded.



Fig. 8: Torque Meter

While in case of dental implant with the horizontal plate and after implant site preparation had been finished the next step was the insertion of the horizontal plate. This procedure was done with the aid of the (commercially pure titanium) horizontal plate insertion guide (Fig.: 9).



Fig. 9: Horizontal plate insertion guide

The horizontal plate insertion guide had been made to engage the three sides' inner slots of the horizontal plate, the horizontal plate insertion guide must have the same round circumference as the part of the disk drill that enters the bone during horizontal plate site preparation (Fig.: 10).



Fig. 10: Horizontal plate insertion guide and disk drill

The function of the horizontal plate insertion guide was to hold the horizontal plate to its appropriate position and prevents it from rotation during dental implant insertion (Fig.: 11).



Fig. 11: The horizontal plate and the insertion guide inside bone block

After the horizontal plate had been positioned in the bone block, the insertion of the dental implant started (with torque meter) and by using hand the horizontal plate insertion guide would prevent the horizontal plate from movement and rotation. The maximum torque meter's readings had been recorded for each dental implant.



Fig. 12: Dental implant in final position

Resonance Frequency Analysis:

Resonance Frequencies Analysis was performed by using the Osstell ISQ Meter (Sweden) (Fig.: 13).



Fig. 13: Osstell ISQ Meter

The specimen of the artificial bone and the implant was mounted to the vice then the smartpeg was attached to the dental implant fixture by using the smartpeg tightening cap then the measurement probe was held close to the top of the smartpeg without touching it (Fig.: 14). When the instrument sensed the smartpeg an audible sound emitted giving the ISQ (Implant stability quotient) value on the display.



Fig. 14: ISQ Value measurements

Four different directions readings for each dental implant were taken, which were mesial, distal, buccal and lingual sides then the implant stability quotient value (ISQ value) were averaged.

Removal Torque Measurements:

The torque meter was used for unscrewing the dental implant fixtures to measure the removal torque values. The removal torque values were measured by taking the maximum reading on the torque meter until the fixtures removed. The unit that used in measuring both insertion torque and removal torque was (N.Cm).

Push-in Force Measurements:

The push-in and pull-out tests were carried out by using a Universal Testing Machine (Tinius Olsen, U.S.A.). The Universal Testing Machine contained two clamps one on the upper part and one on the lower part. In the Push-in test the upper clamp held a metal push-in piece and the lower clamp held bone and implant specimen. After the clamps had been tightened the machine was set to move the upper clamp vertically downward toward the lower clamp at 1mm/min displacement rate ⁽¹¹⁾. The computer that connected to the machine was programed to stop the machine after 5mm displacement and the push-in force value in N would appear on the computer screen.

Pull-out Force Measurements:

The pull-out test was started by attaching the pull-out metal piece to the upper clamp and the bone-implant specimen to the lower clamp after that both machine clamps were tightened. The Universal Testing Machine started by moving the upper clamp vertically upward (away from the lower clamp) at 1mm/min displacement rate until the implant completely pulled out of the artificial bone block ⁽¹¹⁾. The pull-out force (N) would appear on the computer screen.

The number of the specimens were forty for each test, twenty samples were of 5mm length (ten without the horizontal plates and ten with the horizontal plates) while the other twenty samples were of 10mm length (ten without the horizontal plates and ten with the horizontal plates).

RESULTS

Insertion Torque:

The minimum and maximum mean values for the insertion torque test of the 5mm and 10 mm dental implants (with and without the horizontal plates) were respectively 27.627 N*Cm and 50.538 N*Cm.

Resonance Frequency Analysis:

The minimum mean values for the resonance frequency analysis of the 5mm and 10mm dental implants (with & without the horizontal plates) was 43.125 ISQ, while the maximum mean value was 46.200 ISQ.

Push-in force test:

The minimum and maximum mean values for the push-in force test of the 5mm & 10mm dental implants (with and without the horizontal plates) were 865.9 N and 1870.3 N.

Table 1: Mean values & standard deviations of the insertion torques for dental implants without & with the horizontal plates of both the 5mm and the 10mm implants

Dental Implants	Studied groups	N	Mean (N* <i>Cm</i>)	SD
5mm implants	Without the horizontal plates	10	27.627	2.425
	With the horizontal plates	10	36.752	2.681
10mm implants	Without the horizontal plates	10	32.502	1.717
	With the horizontal plates	10	50.538	2.257

Table 2: Mean values & standard deviations of the Resonance Frequency Analysis for the 5mm and the 10mm dental implants (without and with the horizontal plates)

Dental Implants	Studied groups	N	Mean (ISQ)	SD
5mm implants	Without the horizontal plates	10	43.125	1.029
	With the horizontal plates	10	43.850	1.015
10mm implants	Without the horizontal plates	10	45.200	1.224
	With the horizontal plates	10	46.200	1.593

Removal Torque:

The minimum and maximum mean values for the removal torque test of the 5mm and 10mm dental implants (with and without the horizontal plates) were respectively 22.316 N**Cm* and 37.627 N**Cm*.

Pull-out force test:

The minimum and maximum mean values for the pull-out force test of the 5mm and 10mm dental implants (with & without the horizontal plates) were respectively 107.050 N and 874.600 N.

Table 3: Mean values & standard deviation of the removal torques for dental implants without and with the horizontal plates at the two different lengths (5mm and 10mm)

Dental Implants	Studied groups	N	Mean (N* <i>Cm</i>)	SD
5mm implants	Without the horizontal plates	10	22.316	1.886
	With the horizontal plates	10	29.439	1.753
10mm implants	Without the horizontal plates	10	28.691	2.155
	With the horizontal plates	10	37.627	2.633

Table 4: Mean values & standard deviation of the push-in force tests for dental implants without and with the horizontal plates of 5mm and 10mm lengths

Dental Implants	Studied groups	N	Mean (N)	SD
5mm implants	Without the horizontal plates	10	865.9	58.819
	With the horizontal plates	10	1835.7	58.918
10mm implants	Without the horizontal plates	10	1028.5	79.631
	With the horizontal plates	10	1870.3	54.583

To compare between means in each test an independent sample T-test was performed between dental implants without the horizontal plates and dental implants with the horizontal plates for both 5mm and 10mm lengths.

The result showed that there was very highly significant difference (P-value ≤ 0.001) between dental implants with the horizontal plates and dental implants without the horizontal plates of both 5mm and 10 mm lengths in four initial stability tests which were insertion torque, removal torque, push-in test and pull-out test, while the statistical analysis of the resonance frequency analysis showed that there was non-significant difference (P-value ≥ 0.05) between dental implants with the horizontal plates and dental implants without the horizontal plates of both lengths.

Table 5: Mean values & standard deviations of the pull-out force tests for 5mm and 10mm (dental implants without the horizontal plates and dental implants with the horizontal plates)

Dental Implants	Studied groups	N	Mean	SD
5mm implants	Without the horizontal plates	10	107.050	7.041
	With the horizontal plates	10	485.000	29.868
10mm implants	Without the horizontal plates	10	326.450	30.548
	With the horizontal plates	10	874.600	85.676

DISCUSSION

In this study, the design of dental implant had been chosen according to the parameters that help to increase dental implants' success rate. These parameters enhance many aspects like increasing initial stability, providing favorable surface area to allow optimum stress distribution and others.

The shape of the threads was square which agreed with Chun et al. ⁽¹²⁾, who concluded that the square thread design has a beneficial shape for occlusal loading compared with other thread designs. In agreement with Strong et al. ⁽¹³⁾, the thread pitch and thread depth had been chosen to provide maximum surface area without affecting the fixture mechanical properties. The wider crestal area had benefits of increasing initial stability and reducing stresses by increasing surface area which agreed with Misch ⁽¹⁴⁾. The taper self-tapping apical area had been made to facilitate fixture insertion through the bone and the horizontal plate that agreed with Misch ⁽⁷⁾.

The design of the horizontal plate with four holes was made to allow sufficient blood supply across it in case of using the plate for an in vivo studies ⁽⁸⁾.

The solid rigid polyurethane foam blocks' (artificial bone blocks) density had been chosen to simulate the natural trabecular bone density which agreed with Tabassum et al. ⁽⁹⁾.

Many methods had been used to measure dental implant stability and detect stability problems. Several attempts, such as those which were done by Akkocaoglu et al. ⁽¹⁵⁾ and Sakoh et al. ⁽¹⁶⁾, used insertion and removal torque to determine the conditions of the implant–bone interface. However, these methods could only be used during or after implant placement; they could not be used for a long-term assessment. Therefore, their clinical use in implant stability assessment is limited.

Primary stability could be measured after implant

placement and for long term assessment using the Resonance Frequency Analysis (RFA). The RFA technique had numerous advantages in implant stability assessment including non-invasiveness, non-destructiveness and instant determination of results ⁽¹⁷⁾.

The assessment of shear force of the bone–implant interface using the pull-out test which was done by Pfeiffer et al. ⁽¹⁸⁾ and the push-in test that was done by Wu et al. ⁽¹⁹⁾, had been widely used to determine the mechanical strength of the bone–implant integration.

In this study, the evaluation of the initial stability for dental implants was done by using five mechanical assessments that were commonly used in biomedical research for primary stability.

The results of this study indicated that implants with horizontal plates showed significantly higher values in four biomechanical assessments, but the RFA did not show this difference. These results implied that dental implants with horizontal plates had better primary stability compared with implants without horizontal plates in this type of bone density.

In artificial bone models implants with horizontal plates showed statistically higher mean insertion and removal torque values compared with implants without horizontal plates. The difference in the contact areas, which were associated with dental implant design, horizontal plate design and bone type could explain these results.

The optimum torque value is influenced by the geometry of the screw, the contact relationships between the screw and its (bore and threads), the friction coefficient and the properties of the materials used ⁽²⁰⁾.

As mentioned above the maximum torque depended on the properties of the materials that are joined together. In this study, the dental implants without the horizontal plates fixtures were made of commercially pure titanium and joined artificial bone made of solid rigid polyurethane foam while in case of the dental implants with the horizontal plates; the commercially pure titanium fixtures joined the solid rigid polyurethane foam of artificial bone and also joined the commercially pure titanium horizontal plates, so the difference in the properties of the materials that joined together in the above two groups explain the change in the insertion and removal torque values (increased in dental implants with the horizontal plates).

In this study, statistics of the resonance frequency analysis showed that there was non-significant difference between dental implants with the horizontal plates and dental implants without the horizontal plates, these results might be due to the position of the horizontal plates in a deep part from the marginal bone-implant contact area which agreed with Kim and Lim ⁽¹¹⁾ who compared the primary

stability between dental implants with self-tapping blades and dental implants without self-tapping blades. They concluded that the ISQ values do not mirror the bone-implant contact at deeper parts, but rather at the marginal bone region. These results also agreed with Akkocaoglu et al. ⁽¹⁵⁾, who made a radiographic evaluation study and suggested that bone contact, particularly at the marginal region, plays a decisive role in the ISQ value obtained.

A pull-out test is another indirect test of an implant's anchorage potential. It usually measures the tensional force (applied vertically to the surface of bone into which an implant has been inserted) necessary to pull the implant out of bone. The force is applied parallel to the long-axis of the implant ⁽²¹⁾.

Since the pull-out force directed parallel to the long-axis of the dental implant while the horizontal plates positioned perpendicular to the long-axis of dental implant then the implants with horizontal plates required more force to be pulled-out than implants without horizontal plates.

This theory could be also applied to the push-in test since the force of push-in also directed parallel to the long-axis of dental implant but in the opposite direction of the pull-out force. That was why dental implants with horizontal plates showed highly statistically significance increase in both pull-out and push-in force than dental implants without horizontal plates.

The conclusions that can be drawn from this study are:

1. The dental implants with the horizontal plates had better primary stability compared with the dental implants without the horizontal plates in this type of bone density confirming that the horizontal plates enhanced the primary stability of the dental implants.
2. The Resonance Frequency Analysis could not indicate the initial stability of dental implants at deeper parts of bone-implant interface (horizontal plates' position) which mean that only the marginal (crestal) region of bone-implant interface affect the ISQ values.

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