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EFFECT OF IMPLANT PLATFORM SWITCHING ON STRAIN DEVELOPED AROUND IMPLANTS WITH STRAIGHT AND ANGLED ABUTMENTS

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ABSTRACT

Statement of the problem. Implant placement in an ideal position where stresses are transmitted vertically along the long axis of the implant rarely if ever coincides with the most esthetically pleasing position dictated by prosthetic planning. This situation could be dealt with by placing the implant at an angle in the most favourable position surgically and using angled abutments to compensate for the deviation from the previously planned prosthetic site of the final restoration. This may lead to excessive stresses on the inclined side of the implant which could cause bone resorption.

Purpose. The aim of this study was to evaluate the effect of implant platform switching on strain developed around implants with straight and angled abutments.

Materials and Methods. Twenty root-form titanium implants were inserted in epoxy resin blocks. According to the direction of implant insertion in the epoxy resin block, the twenty implants were divided into two main groups: **Group I: (n=10)** Straight implants with straight abutments. **Group II :(n=10)** Inclined implants with angled abutments (15 degrees). Each group was sub-divided into two sub-groups according to the abutment diameter in relation to the implant diameter: **Sub-group A :(n=5)** 4.5 mm diameter Implants received 4.5 mm diameter abutments. **Sub-group B:(n=5)** 4.5 mm diameter Implants received smaller 3.75 mm diameter abutments (platform switching). The 20 implant abutments received Ni-Cr full metal crowns. The blocks were trimmed to 1mm thickness around the implant then each sample received four strain gauges to represent the mesial, distal, buccal and lingual surfaces around the implant. A computerized universal testing machine was used for loading the implants by 300N, at a rate of 1 N/Sec. The load was applied progressively starting from zero to 300 N during which readings from the strain meter were recorded on the computer.

Results. It was found that **Group II** (Angled abutments) with matching diameter **Sub-group A** showed statistically significantly ($P \leq 0.05$) highest mean micro-strains (435.1± 215.7) followed by **Group I** (Straight abutment) with matching diameter **Sub-group A** (346.2 ± 175.3) followed

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by **Group II** (Angled abutments) with platform switching **Sub-group B** (307.1 ± 135.0). **Group I** (Straight abutment) with platform switching **Sub-group B** showed statistically significantly lowest mean micro-strains (239.0± 165.4) .

Conclusions. Straight implants with straight platform-switched abutments were associated with the least micro-strain values.

KEYWORDS: Implants, platform-switching, angled abutments, implant supported crowns, crestal bone resorption, strain.

INTRODUCTION

The introduction of osseointegrated endosseous dental implants helped revolutionise the delivery of dental prosthetic work. Patients are offered more retentive, stable and esthetically pleasing restorations that helped overcome uncomfortable solutions.

The use of implants in dentistry varies from replacement of a single missing tooth to full mouth rehabilitation. Cases that were once limited to removable partial dentures such as long edentulous spans and free end saddles are treated by implants. Replacement of a single missing tooth with an implant also helps in conservation of sound tooth structure of adjacent teeth that would have been reduced as abutments if a conventional fixed partial denture was provided. [1]

Long term Success of endosseous dental implants depends to a large extent on successful osseointegration, amount of stresses developed in bone surrounding osseointegrated dental implants during function, esthetic outcome of the final restoration and overall oral health. [2]

Ideally, implants should be placed parallel to each other and to adjacent teeth and be aligned vertically with axial forces. However, achieving this may not be possible owing to deficiencies in the ridge's anatomy. [3] The placement of an esthetically pleasing restoration may be limited by the availability of bone of sufficient quantity and quality. Vital anatomical structures usually dictate the position of the implant within bone, which may not coincide with prosthetic planning to obtain a functioning esthetic restoration.

In these challenging situations, there are two commonly used options, the first involves surgical procedures to prepare the planned implant placement site and those may include sinus lifting, nerve repositioning and ridge augmentation. The second option is placing the implant in the area of greatest bone available, then using a different abutment angulation and prosthetic modifications to achieve the desired esthetic result. The use of angled abutments could thus spare the patient the morbidity associated with corrective surgical procedures as well as overall cost and duration of the whole treatment period.[4]

The use of angled abutments has its own share of inconveniences where forces are no longer transmitted along the long axis of the restoration, which carries with it higher stress and strain values in bone surrounding the implant. However, the use of angled abutments is widely accepted as the stresses are within or slightly above the physiological limit. [5]

Platform Switching is a concept which aims at reduction of the crestal bone loss around the implants and involves the restoration of implants with smaller diameter abutments such that the implant abutment junction is horizontally repositioned inwardly and away from the outer edge of the implant platform. Several advantages were found regarding the concept of platform switching, stresses transmitted to the bone implant interface in the crestal region was reduced [6], better esthetic outcomes[7] and reduced bone loss in the crestal region [8].

Cimen and Yenging (2012) [6] stated that platform switching may contribute to reduce the stress level at the implant-bone interface area . The reduction of stress concentration at the implant-bone interface area is a favourable development to ensure the continuity of osseointegration.

Canullo et al (2009) [9] observed that implants restored according to the platform-switching concept experienced significantly less marginal bone loss than implants with matching implant-abutment diameters.

On the other hand, ***Crespi et al. (2009)*** [10] found no differences in the bone level changes between platform-switched implants and conventional matching diameter external-hexagon implants after 24 months.

Vigolo et al (2009) [11] reported the longest follow up (5 years), with a positive effect of platform switching on bone preservation after 1 year. However, at 5 years the marginal bone change was insignificant as compared to that seen at 1 year around both switched and non-switched platforms. These results suggest that under normal circumstances, the pattern of marginal bone loss associated with platform switched implants was identical to that of conventional implants, where the greatest amount of bone changes occurred between surgery and crown/abutment placement, after which the changes were minimal.

Hsu et al (2009) [12] conducted a 3D Finite Element Analysis and reported that platform switching leads to a small but insignificant reduction of <10% in crestal bone strain. However, it does not significantly influence crestal bone strain or micro movement. Thus the aim of this study was to evaluate the effect of implant platform switching on strain developed around implants with straight and angled abutments.

Methodology

Twenty root-form titanium implants were inserted in epoxy resin blocks fabricated in a specially designed interlocking copper mould 2cm x 2cm x 2cm**.** The copper mould consisted of four side walls and a base, each numbered to facilitate their assembly.

A paralleling device was fabricated to ensure correct positioning of the implants in the epoxy block. According to the direction of the implant insertion in the epoxy resin block, the twenty implants were divided into two main groups: **Group I: (n=10)** Straight implants with straight abutments. **Group II :(n=10)** Inclined implants with angled abutments (15 degrees).

Each group was sub-divided into two sub-groups according to the abutment diameter in relation to the implant diameter: **Sub-group A :(n=5)** 4.5 mm diameter Implants received 4.5 mm diameter abutments. **Sub-group B :(n=5)** 4.5 mm diameter Implants received smaller 3.75 mm diameter abutments (platform switching).

After screwing of each abutment into its corresponding implant **Figures (1 and 2)**, full metal crowns representing upper premolar were constructed on all abutments from a biocompatible nonprecious nickel chrome based alloy (I-Bond

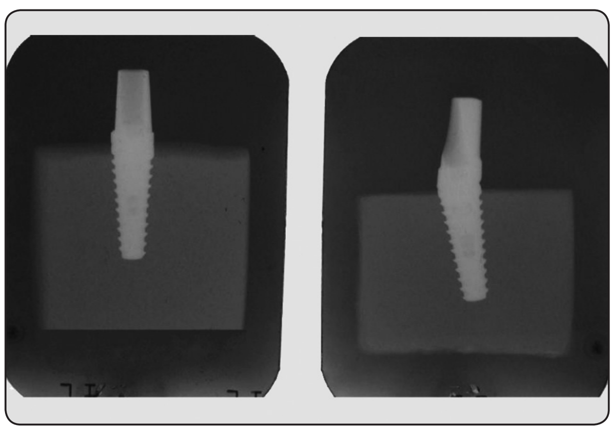

Fig. (1): X-rays showing matching diameter straight (left) and angled (right) abutments.

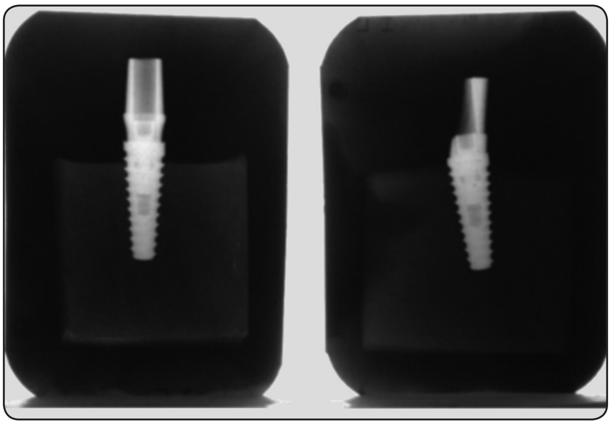

Fig. (2) X-rays showing Platform-switched straight (left) and angled (right) abutments.

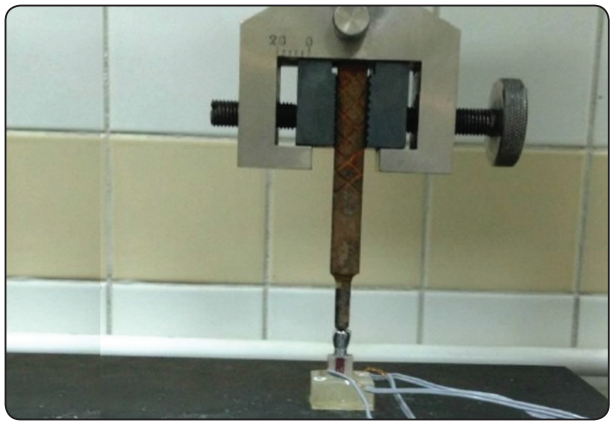

Fig. (3) Loading of the sample in the universal testing machine

O2, Interdent, Slovenia) following a standardized protocol.

A specially designed cementation device was constructed to apply a constant axial load to the crowns during cementation. A temporary zinc oxide non-eugenol cement (RelyX Temp NE, 3M ESPE, Germany) was used.

Each epoxy resin block was modified to receive four strain gauges, one on each side of the implant. After connecting the strain gauges to the strain meter, a universal testing machine was programmed to apply a load of 300N, at a rate of 1 N/Sec **Figure (3)**. The load was applied progressively starting from zero to 300 N during which readings from the strain meter were recorded on the computer. All measurements were performed by a single examiner in a standardized environment**.**

RESULTS:

Data were presented as mean and standard deviation (SD) values. Data were explored for normality by checking data distribution, histograms, calculating mean and median values and finally using Kolmogorov-Smirnov and Shapiro-Wilk tests of normality. Kruskal-Wallis test was used to compare between the four groups. Mann-Whitney U test with Bonferroni's correction was used for pair-wise comparisons when Kruskal-Wallis test is significant.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Data showed non-parametric distribution; So Mann-Whitney U test was used to compare between the two abutment diameters as well as to compare between the two abutment angulations.

Total mean strain values and standard deviation of all four groups were summarized in **table (1)** and graphically drawn in **figure (4)**. It was found that **Group II** (Angled abutments) with matching diameter (**Sub-group A)** showed statistically significantly ($P \leq 0.05$) highest mean strain (435.1± 215.7) followed by **Group I** (Straight abutment) with matching diameter **(Sub-group A)** (346.2 ± 175.3) followed by **Group II** (Angled abutments) with platform switching (**Sub-group B)** (307.1 ± 135.0). **Group I** (Straight abutment) with platform switching (**Sub-group B)** showed statistically significantly lowest mean strain (239.0± 165.4)

Table (1): Descriptive statistics and results of comparison between total strains induced by the four groups

Group	Mean	SD	P-value
Straight abutments with Matching diameter	346.2 [b]	175.3	<0,001 *
Angled abutments with Matching diameter	435.1 [a]	215.7	
Straight abutments with Platform switching	239.0 [d]	165.4	
Angled abutments with Platform switching	307.1 [c]	135.0	

** Significant at P ≤ 0.05, Different superscripts are statistically significantly different*

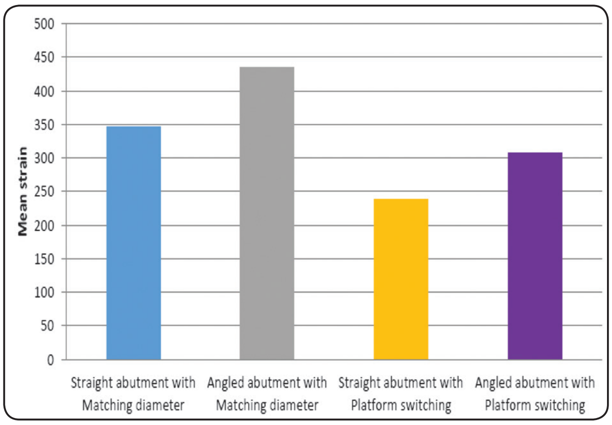

Fig. (4) Bar chart representing comparison between total strains induced by the four groups

DISCUSSION

Angled abutments allow placement of implants in the most favorable available bone in patients with compromised osseous anatomy, and compensate for buccolingual and mesiodistal implant angulation problems. several authors observed the high survival rate of implants loaded via angled abutments, as well as, the excellent esthetic and functional outcomes achieved with these types of abutments. The use of angled abutments allowed restorations to be parallel and aligned with each other. [4,13,14]

Changing the Implant inclination caused higher strain than the conventional direction.[3] Therefore, in this study two different directions, straight versus angled, were examined to evaluate the effect of implant direction on the strains produced.

Implant design was found to play an important role in long-term success of the esthetic outcome of implant-supported crowns. [15] By eliminating or reducing crestal bone resorption, the papilla and the facial gingival marginal tissues are supported. Soft tissue support is critical for establishment and sustainability of functional and aesthetic outcomes. [16]

The main causal factors of crestal bone loss are occlusal overload and peri-implantitis.[17] Hence, occlusal stress and strain developed around platform switched implants was chosen as the focus of our study.

Platform-switching concept, when first discovered, was accompanied by a favorable response regarding crestal bone level around the implant, which was confirmed by further studies. [18,19]

Platform switching has been correlated with preservation of crestal bone level. [9] There are many hypotheses on how platform switching reduces crestal bone resorption. One of those hypotheses is that platform switching influences the biomechanical stress distribution on surrounding bone leading to its preservation. [8]

Abutments diameter chosen for this study was 4.5 mm for the matching diameter group and 3.75 mm for the platform-switched group. The 3.75 mm diameter was chosen for the platform-switched group to obtain a 0.75 mm difference in diameter according to the recommendations of 0.5-0.75mm difference mentioned by ***Canay S and Akça K (2009).*** [17]

The selection of a smaller size abutment rather than using an expanded platform to obtain platform-switching was based on the conclusions of **Rodriguez-Ciurana et al., 2009** [20] who failed to obtain peri-implant bone force attenuation values as high as those reported in earlier studies, when comparing platform expansion with a traditional restoration model.

Titanium implants were used in the present study. Titanium is a nonessential trace element that has proven to be extremely biocompatible through a thin surface film of titanium dioxide. [21]

Rodriguez-Ciurana et al (2009) [20] concluded that force dissipation in the platform switching restoration is slightly more favorable in an internal than in an external junction, since it improves distribution of the loads applied to the occlusal surface of the prosthesis along the axis of the implant. This was the reason for choosing an internal hex system in the present study.

In the present study, the strains were measured on the area of epoxy resin block adjacent to the implant body. Implants were embedded in epoxy resin blocks to simulate implant embedded in bone. Epoxy resin was chosen as it was documented that its modulus of elasticity possesses approximate value to that of human bone, as the supporting structures are an important factor that affects stress distribution. Epoxy resin has high hardness that can withstand the applied force during mechanical testing without fracture and has the same compressive index of bone.[22,23]

Brosh et al (1998) [24] mentioned the advantages of the strain gauge technique in measuring micro strains that can be applied to more complicated implant cases simulating clinical situations. The numerical results provided by strain gauge analysis provides valuable information while other methods could be used as complementary aids. Hence, strain gauge analysis was used in the present study.

A study showed that the range of occlusal forces varied according to location; maximum occlusal forces are 400 to 890 N in the molar region, 222 to 445 N in the premolar area and 89 to 111 N in the incisor region.[25] According to the previously mentioned range of values, 300 N was chosen for loading the implants in the present study.

Regarding the results of this study, matching diameter abutments showed statistically significantly higher mean micro-strain than Platform-switched abutments regardless of the abutment angulation.

These results were in accordance with those of ***Cimen and Yenging (2012)*** [6] who studied the effect of platform switching on stresses in bone and implant-abutment complex. They stated that platform switching may contribute to reduce the stress level at the implant-bone interface area. The reduction of stress concentration at the implant-bone interface area is a favourable development to ensure the continuity of osseointegration.

When straight and angled implant abutments were used, a significant difference was observed between the two types, implants restored with straight abutments showed less micro-strain than those restored with angled abutments. This was in agreement with ***Sallam H (2005)*** [26], who reported that bone density increase around implants loaded via straight abutments may be due to the favorable tissue reaction towards the favorable stresses transmitted through the straight abutments, to the implants and to the supporting structures.

Implant stress and strain concentrations were highest in group II (Inclined implants with angled abutments regardless of abutment diameter) due to the bending moment effect of these abutments. These effects indicate that implants should be placed along the direction of axial loading of proposed prosthesis to obtain a better stress-strain response and this was in agreement with ***Lin C et al (2008).*** [27]

CONCLUSION

Within the limitations of this in vitro study the following conclusions could be drawn:

1. Platform-switching and angulation of the abutments significantly affect micro-strains developed around implants.
2. Platform-switched abutments reduces micro-strains developed around implants regardless of the abutment angulation.
3. Straight implants with straight abutments are associated with lower micro-strain values than inclined implants with angled abutments with both abutment diameters.
4. Straight implants with straight platform-switched abutments are associated with the least micro-strain values among all groups.
5. Inclined implants with angled matching diameter abutments are associated with the highest micro-strain values among all groups.

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