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THE EFFECT OF DIFFERENT ABUTMENT FINISH LINE CONFIGURATION ON STRESS DISTRIBUTION OF IMPLANT SUPPORTED ZIRCONIA FIXED PARTIAL DENTURE

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ABSTRACT

Purpose: to study the influence of different abutment finish line configuration on stress distribution of implant supported fixed partial denture.

Materials& Methods: Two endo-osseous screw vent implants for 2nd premolar and 2nd molar were chosen and placed parallel to each other. After resin model construction, Implants were attached to the corresponding abutments group according to the finish line configuration of the abutments. Group A: standard abutment with circular contour, Group B: anatomical abutment with anatomical contour. The fixed partial denture was designed with a flat area on the occlusal surface to accommodate for the loading pin tip each time. Strain gauges were adhered to four different sites (buccal, lingual, mesial and distal) and a force of 200N over 30 seconds duration and maintained for 30 seconds also. Then forces were removed and residual strains were released for 2 minutes.

Results: One-way ANOVA used to compare between different abutment finish line configuration and teeth for mean Strain (μm/m) and total strain followed by Tukey's post-hoc test for pairwise comparison. Significant level set at $p < 0.05$.The results revealed that all types of abutments have a certain level of misfit, which resulted in measurable strains. Significant difference was found between the different groups of the finish line configuration (standard & anatomical).

Conclusion: Difference in abutment finish line configuration may affect the stress pattern induced around dental implants.

Clinical significant: implant abutment with anatomical finish line configuration is a preferred selection for better stress distribution.

KEYWORD: anatomical abutment finish line, circular abutment finish line, stress analysis, misfit.

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INTRODUCTION

Implant-supported prostheses have considered one of the most popular treatment options in the last years with long-term clinical success rates and proven functional, biological and mechanical advantages. Their impressive performance has motivated the search studies and researchers to work on it.

Implants exhibit biomechanical behaviors that are different from those of natural teeth because implants, lacking periodontal ligaments, are in direct contact with bone. Consequently, occlusal loads received by the implant are directly transferred to the surrounding bone structure. This relationship affects the stress distribution in implants and peripheral bone, which is one of the major factors determining the implant success. The stress or energy transfer between implant and peripheral bone is affected by factors such as the direction of loading, the implant abutment design and material as well as the selected superstructure material, design and construction(1,2).

The natural appearance of ceramic restorations has made them the treatment of choice for anterior and posterior. CAD/CAM technology with advantages of the speed, simplicity and efficiency is considered a good choice for constructing ceramic restorations. However, the esthetic advantage must be considered against the possible lack of good marginal adaptation, which is essential for the clinical success and quality of all ceramic restoration. In implant supported restoration, lack of proper adaptation may result in increased plaque accumulation, ultimately leading to periodontal disease, difficulty to remove cement and stress concentrated at the cervical area of the implant(3).

Furthermore, a gap between the implant components may create a microleakage allowing the passage of acids, enzymes, bacteria with their metabolic products that directly affect the periodontal tissue, causing bleeding, and swelling and may trigger the development of peri-implantitis with subsequent bone loss and implant failure. These bacteria are present on all surfaces; outside, between the implant components as reported by many studies. Therefore, an absolute and passive fit of the abutment to the implant has been considered as prerequisite for long-term clinical success(4).

When comparing different ceramic materials, zirconia showed significantly higher fracture load. To date, CAD/CAM technology is the only method of constructing implant abutments and superstructure from high-strength partially stabilized zirconia. Researches mentioned that implant-supported zirconia restorations in the esthetic zone should be used with caution, because limited clinical evidence of their performance is available(3).

On the same side, the ideal aesthetics and durability of the implant supported restoration may be attributed to the correct contour of the selected abutments with proper frameworks construction. Employment with anatomical contour has been found to minimize the risk of veneering ceramic chipping but may affect the transferred load. Furthermore, implant superstructure should exhibit a natural emergence profile that simulate natural tooth contour to support the peri-implant soft tissues. Moreover, appropriately contoured abutments can improve residual cement removal in case of cemented restorations and finally decrease complications associated with residual cement(3,4,5).

In the case of the cement-retained restoration, to facilitate cement material removal, the finish line should be closely related to the soft tissue contour and follow the mucosal outline(5). However; few studies are currently available on the effects of the curvature of the abutment finish line for other ceramic restoration systems.

A study by Nakamura et al (6) about effect of finish line configuration on microbial activity, it was reported that the circular finish line can cause more biofilm mass and higher amounts of microorganisms concentration. The non-anatomical curvature of the implant abutment is one of the factors that favoring the microbial adhesion on circular (standard) finish line configuration. On the other hand, anatomical finish line configureation has been described to have a potentially lower susceptibility for bacterial adhesion and some studies have suggested that the sweeping as gingival architecture is favorable for microbial control[7]. Also, many studies mentioned that the esthetic outcome with anatomical finish line configuration is much preferred[8,9].

The relation between finish line shape and stress distribution is still not predicted. A few limited studies about this were performed[8,9].

The purpose of the present study was to study the influence of different abutment finish line configuration on stress distribution of implant supported fixed partial denture. The null hypothesis was that the standard circular finish line configuration shows favorable stress distribution than anatomical finish line.

MATERIALS AND METHODS

Two endo-osseous screw vent implants (implant direct LLC, 27030 Malibu Hills Road Calabasas Hills, CA 91301 USA) with the following dimensions (13 mm length, 3.8 mm upper diameter and 3.4 mm lower diameter) for 2nd premolar and (13 mm length, 4.5 mm upper diameter and 3.8 mm lower diameter) for 2nd molar were chosen and attached to the their corresponding abutments (implant direct LLC, 27030 Malibu Hills Road Calabasas Hills, CA 91301 USA) using wrench (implant direct LLC, 27030 Malibu Hills Road Calabasas Hills, CA 91301 USA) of torque 30Ncm and a 1.25 mm hex tool.

The implants were placed parallel to each other using the parallometer in its corresponding sockets in the anatomically correct mandibular model (Kilgore Int.Inc., Cold water, mish, USA). Sleeve impression analogue was attached to its corresponding abutment.

Addition silicon polyvinyl siloxane (Aquasil LV, Putty/Light Body, Dentsply, Germany) was selected for pick up impression then the implants were placed in its position in the impression.

Auto-polymerized epoxy resin (Kilgore Int. Inc., Cold water, mish, USA) was mixed according to manufactures instructions, poured into implant impression and left 24 hours for complete polymerization. The same model was used for the different 2 abutments design test groups by replacing only the abutment before model scanning for fixed partial dentures construction in order to diminish the human errors and standardize the implant location.

The difference between the two groups was mainly related to the finish line configuration of the abutments (Figure:1).

Group A: standard abutment with circular contour (Implant Direct™ Dentistry ScrewPlant Full Contour Lab Abutment).

Group B: anatomical abutment with anatomical contour (Implant Direct™ Dentistry Legacy Straight Contoured Titanium Abutment).

The model was sprayed with Cerec Optispray optical reflection medium (Sirona USA, LLC-A Westinghouse Blvd. Charlotte, NC 28273 USA) then scanned using omnicam scanner. Five full anatomical fixed partial dentures in each group were designed and standardized using Inlab SW 15. The fixed partial denture was designed with a

Fig. (1) Standard standard abutment with circular contour and anatomical abutment with anatomical contour

60μ die spacer, 1000μ thickness for the radial and occlusal surface considering that a flat area was designed on the occlusal surface to accommodate for the loading pin tip each time. Furthermore, connector dimensions for the premolar/ molar were adjusted to be 4x4mm according to manufacturer's recommendation.

In Coris TZI media block was used for milling the fixed partial dentures using Sirona MCXL taking into consideration the shrinkage data in the barcode of the block itself. All samples were sintered in an inFire HTC speed high-temperature furnace (Sirona Dental System GmbH, Germany). Finally, samples were tried in their corresponding abutments, finished and polished.

Rely X provisional cement (3M ESPE AG. Dental products D-82229, Seefeld: Germany) was used to cement all samples to their corresponding abutments. A specially designed cementing device was used to apply a constant load of 3 Kgs for 5 minutes with a tin foil sheet on the occlusal surface of the samples to allow even load distribution during cementation.

Four different sites (buccal, lingual, mesial and distal) of epoxy was prepared using 400 grit silicon carbide abrasive paper (Renfert GmbH, Untere Giebwiesen 2, 78247 Hilzingen, Germany) for installation of strain gauge (CC-33A; Kyowa, Tokyo, Japan) with 10 mm length and 1 mm width using gauges adhesive in a parallel position to their respective long axis. Strain gauges left for 24 hours for curing. Then, gauges were connected to different channels of strainmeter.

A universal testing machine (LIoyd Instruments Ltd, Steyning Way, Bognor Regis, West Sussex, PO22 9ST) was used at cross head speed of 0.5 mm/min to apply a vertical static load through a special rod applicator with round end of 6 mm diameter. This applicator was centered in the pontic fossa with a foil in between to ensure equal stress distribution (Figure 2).

Strain gauges were set to zero at 1st using force of 200 N over 30 seconds duration and maintained for 30 seconds also. Then forces were removed and residual strains were released for 2 minutes.

Reading of the strains was taken in microstrain units from the multichannel strainmeter. The load was repeated five times for each sample to ensure the reproducibility of the results. The arithmetic mean and standard deviation of the five readings which were recorded under each loading condition were calculated and tabulated.

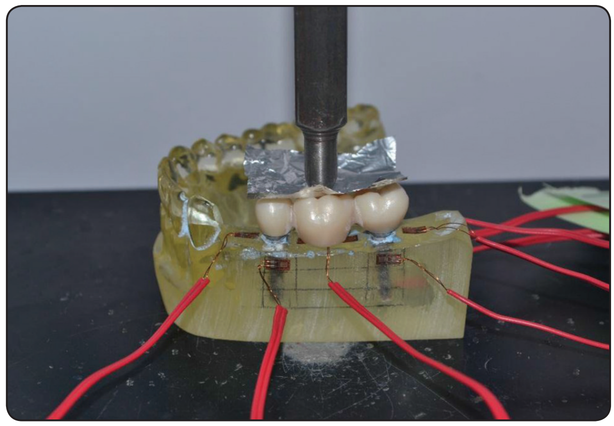

Fig. (2) Load application

RESULTS

Data statistically described in terms of mean and standard deviation (SD). Data explored for normality using Kolmogorov Smirnov test. One-way ANOVA used to compare between different abutment design and tooth for mean Strain (μm/m) and total strain followed by Tukey's post-hoc test for pairwise comparison. Significant level set at $p < 0.05$.Statistical analysis was performed with IBM® SPSS® (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 25 for Windows.

The strain development for the tested implant abutments as it occurred during loading is presented in table (1). The results showed that all types of abutments have a certain level of misfit, which resulted in measurable strains. Significant difference was found between the different groups of the finish line configuration (standard & anatomical). Figure(3).

TABLE (1) Mean and standard deviation (SD) for Strain (μm/m) of abutment surfaces for each abutment finish line design and tooth.

Strain (μm/m)	Standard				Anatomical				
	Molar		Premolar		Molar		Premolar		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Distal	26.67[b]	2.50	68.33[a]	6.61	23.89[b]	3.33	63.89[a]	7.41	≤0.001*
Buccal	55.00[b]	4.33	111.67[a]	10.90	51.11[b]	5.46	108.89[a]	14.31	≤0.001*
Mesial	35.00[a]	4.33	13.33[b]	2.50	32.22[a]	3.63	10.56[b]	5.83	≤0.001*
Lingual	31.67	9.01	16.67	2.50	13.89	42.63	13.89	6.51	0.277 NS
Total	37.08[ab]	12.15	52.50[a]	41.58	30.28[b]	24.90	49.31[a]	41.87	0.014*

Means with the same litter within each row indicates insignificant at p≥0.05 ****=significant, NS= Non-Significant***

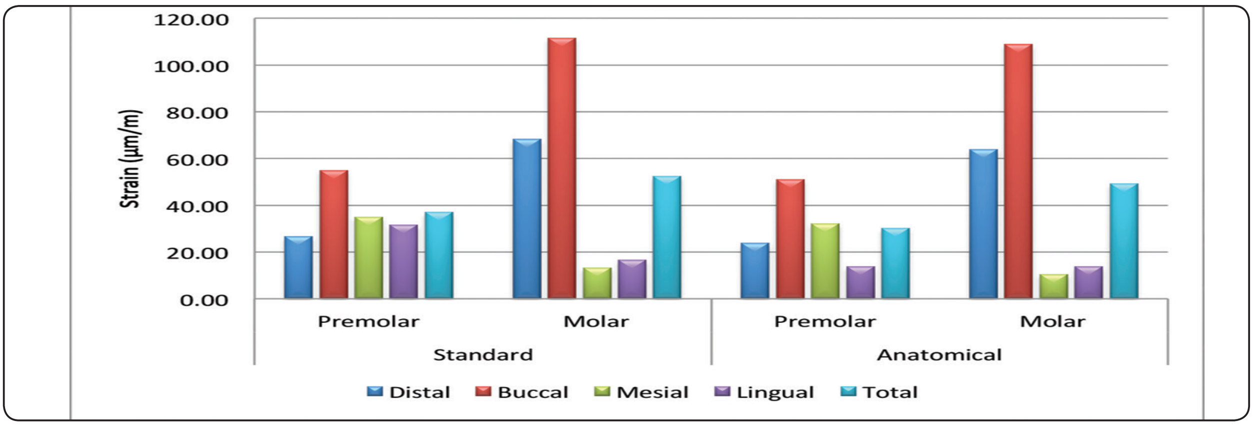

Fig. (3) Bar chart showing the mean Strain (μm/m) for different abutment surface for each abutment finish line design and tooth.

DISCUSSION

During the past few decades, the use of implant supported restorations has been markedly increased. The success of osseo-integrated implant is largely affected by many factors as the way of mechanical stresses transferred from the implant to the surrounding bone, the abutment designs and materials and also the selected superstructure. [10,11]

In the same way, the outcomes of an implant supported FPDs are mostly rely on the biomechanical load control. Excessive functional loading on implants may cause high stress gradients and bending moments that induce bone resorption around implant collar, adversely affecting implant osseo-integration and might lead to implant failure. [12]

Previous studies [13-14] have shown that stresses around implants concentrate primarily in the cortical bone. Thus the precise experimental reproduction of both cortical and canculous bone stiffness is desirable in investigation of stress / strain distribution around implant supported fixed partial denture. Epoxy resin was the material of choice as a bone simulant because of its elastic modulus that simulating the human cortical bone and its stiffness similar to human canculous bone [14]. However, the search for the maximum strain of different type of bone is beyond the scope of the present study.

Rapid progress in CAD/CAM technology and its applications in all dental fields including implant supported restorations became a superior choice in everyday work. CAD/CAM is commonly used for fabrication of customized implant abutments with superstructure. The ideal digital abutment/ restoration design with subsequent final esthetics is greatly affected by the limitations of CAD software and the need to experienced laboratory technician. [15] Several clinical studies have shown that zirconia ceramic have sufficient strength to function as FDP. [16-17] In the current study, definitive three unit full contour translucent zirconia implant supported fixed partial dentures were fabricated.

Passive fit has been described as one of the primary objectives when fabricating implant-supported restorations. Regarding all FPDs investigated in the current study, measurable levels of microstrains were reported. Therefore, it can be concluded that the FPDs investigated had a certain degree of misfit despite being fabricated by the same technician and examined to be within the clinically accepted criteria. [14,18,19]

Other variables like different impression techniques, laboratory analogues, implant components with varying degrees of precision [20,21], type of superstructure retention (screw retained & cement retained) as well as type of cement and patient biting force are affecting also the implant superstructure passive fit. Therefore, the magnitude of strain development depends mainly on the accuracy achieved in the fabrication technique of fixed restorations [19-21].

Electrical resistance strain gauges have been used by many authors in several situations where strain is to be evaluated[22-23]. Bonded electrical resistance strain gauges technology was selected for the purpose of evaluating the strain that resulted at the abutment during the different stages of the experimental study. The dimension of the strain gauges used (length 10 mm, width 1mm) allowed them to be installed without interference with the prosthesis. Strain gauges were adhered to the four surfaces around the implant to monitor the stress in the four planes of motion. This is in agreement with Karl et al[10].The high degree of sensitivity of the strain gauges allowed detection of minute strain changes.

Point of load application, in this study load was applied at the central fossa of the pontic. This was in agreement with Karl et al. [10] who stated that a maximum bending stress in the FPD is induced when the load is applied at the central part of the pontic. According to the loading profile, a defined force of 200 N was applied to the pontic (this peak of load was within the range of maximal posterior occlusal forces for fixed prosthesis supported by implant. After 30 sec the force was reduced to 100 N and applied for 3min (within the range of average human chewing frequency) [9].

Angle of load application in this study load was vertically parallel to long axis of the implant fixture, whereas angled loading corresponding to masticatory or Parafunctional activities could not be reproduced in the present study as was previously performed by Att et al [8].

The results of the current study compared the biomechanics of full anatomical three unit zirconia implant supported fixed partial denture in relation to different abutment finish line configuration. Generally, the results of the strain development was higher for the posterior abutment (molar implant abutment) when compared with the anterior abutment (premolar implant abutment), regardless of finish line configuration table (1). There were significant differences between both records which were in agreement with Karl et al. who explained that the wider occlusal table of the molar distributes stresses more favorably and leads to less strain development around the molar implant abutment in comparison with the premolar implant abutment [10].

According to the results of the static loading at 200N table (1), the results of the strain development at the different stain gauges sites were higher for the buccal and lingual strain gauge of the implant abutment. When compared with the mesial and distal strain gauges. The same pattern was observed with all magnitudes and points of load application for the different finish line configuration. This could be attributed to the fact that stress concentration at the buccal and lingual strain gauges was much higher than that recorded for the mesial and distal sides. It may be attributed to the fact that with vertical loads the tensile and compressive stresses will concentrate at both buccal and lingual surfaces of the cortical bone surrounding the cervical region of the implant rather than the mesial and distal sides of the implants[8,9,24,25].

Contradictory results were observed by mish et al. [26] who stated that strain gauges next to the edentulous span were bounded on the surface that was nearly perpendicular to the plane of bending .Thus , deformation on this surfaces was attributed to both axial force and bending moment generated by loading the implant superstructure. This was in agreement with previous studies[22-24, 26-28].

According to the results of the static loading at 200N table (1), the results of the strain development at the different finish line configurations were higher for the standard finish line configuration when compared with the anatomical finish line configuration. That may be due to larger surface area of the anatomical finish line giving more area for stress distribution and simulating the natural gingival contour also[3,6,7].

The null hypothesis of the present study was rejected and the anatomical finish line configuration was a preferred option.

CONCLUSION

Difference in abutment finish line configuration may affect the stress pattern induced around dental implants. Implant abutment with anatomical finish line configuration is a preferred selection for better stress distribution.

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