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Research Article

Effect of different implant positions on strain developed around four implants supporting a maxillary overdenture with milled bar attachment: An in vitro study

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Abstract

Background: Implant-supported overdentures are a use full treatment modality for edentulous patients. the implants retain dentures was a big improvement for the patients and offered new treatment alternatives. The aim was to evaluate and compare the effect of two different implant positions on strain developed around four implants supporting a maxillary overdenture with milled bar attachment. **Methods:** Construction of A (3D) maxillary acrylic model was done from a cone beam computed tomography of an edentulous patient. Four implants were inserted bilaterally into an acrylic resin model in canines and premolar regions. Experimental overdentures with metal housings were constructed for each group to be connected to the implants in canine area with milled bar attachment (group I) or connected to the implants in premolar area with milled bar attachment. Four linear strain gauges were bonded to the acrylic resin at the buccal and palatal surfaces of each implant. Strains were measured by using strain gauges by the aid universal testing machine to apply load at unilateral (canine and premolar side) and bilaterally. the data was collected and analyzed**. Results:** The result shown that strain was highest record at canine than premolar with either unilateral, or bilaterally loading. **Conclusion:** Within this study limitations, stresses are higher at the inserted implant at the canine area than those inserted in premolar area in milled bar attachment cases.

Keywords: Implant position, maxillary implant overdenture, milled bar, Stresses.

Introduction

Implant-supported overdentures are a use full treatment modality for edentulous patients. the implants retain dentures was a big improvement for the patients and offered new treatment alternatives. Different aspects, such as mastication, stability, comfort, speech, food choice, psychological factors, and impact on social activities could be optimized Implant-retained maxillary overdenture is a solution to improve retention. At least 4 implants are required for implant-retained overdenture. Moreover, the smaller number of implants are preferable to minimize the surgical invasion and the economic encumbrance for the patient. [1-2]. The attachments used to connect the overdentures to the implants include ball anchors, magnets, and bars.

Milled bar overdentures are required (four to six) implants which rigidly connected by two or more milled bars. The removable overdenture, presents an inner metals or acrylic supra structure.[3]The supra-structure of milled bar overdenture is recommended to be thin as much as possible to provide space for the rest of the other components.[4]The materials used in casting the milled bars may be precious metal or non-precious metal alloys such as cobalt chromium or titanium

Milled bar retained implant maxillary overdenture using either anterior or posterior was evaluated. The overdentures rigidly anchored on implant with milled bar showed a low rate of prosthodontics maintenance requirements. A high survival rate, low rate of prosthodontics complications and acceptable peri-implant conditions when implants placed either in the (anterior /posterior) maxilla. Besides this, the used of the milled bar for rigid anchorage combines many favorable prosthodontics features for removable prostheses and fixed prostheses[4].

The aim of the present study was to evaluate and compare the effect of two different implant positions on strain developed around four implants support in maxillary overdenture with milled bar attachment. The hypothesis was that certain implant positions can minimize peri-implant strain.

Material and Methods:

Experimental maxillary casts

This an in -vitro study was performed on the same maxillary resin model for standardization to representing a completely edentulous maxillary arch with four implants installed at both canine and second premolar areas. A Cone-beam computed tomography (ICAT next generation, imaging sciences international – Hatfield –PA- USA) of maxillary edentulous patient was taken for diagnostic reasons to plan an implant supported maxillary overdenture. Then, the CBCT digital image was transformed to STL (STereoLithography) file software (real guid 5, 3diemme, Germany). construct a resin model by using of a 3D printing machine (Method X, Makerbot, USA) used this file software (PLA PLUS/PLA + filament, Shenzhen Esun, China) to simulate edentulous maxilla in the same manner as the 3d printed surgical guide is constructed in any computer guided implant insertion technique clinically

Mucosal simulation & Implants insertion

By the help of 3D model the surgical guide was constructed and the artificial teeth setting was done and the four holes of implant and retentive pins were determined, then the surgical guide was printed by using 3D printing machine (Printer mogassam dent 2 – Cairo-Egypt) to photo initiator acrylic resin (Harz Labs LLC., Moscow-Russian). Acrylic resin trial denture base was constructed on the model by using photo initiator acrylic resin. A pilot drill was used to determine the osteotomy site by help of the guide template, then the Successive twist drills was used to increase the diameter until reach the final drill. 4 implants (TioLogic, Dentaurum, Ispringen, Germany) (4.2 mm in diameter and 13 mm in length) were attached in the canine and second premolar areas bilaterally using auto-polymerized acrylic resin to simulate osseointegriation. The holes of the implants were closed using the cover screw to avoid their clogging with the resilient liner material residues during processing of mucosal simulation. The stone model (GH- Dental stone, Egypt) was flask with wax spacer. Then wax elimination was completed to remove the wax spacer and create a mold cavity of mucosal simulation. For the model, an approximately 2-mm-thick layer of autopolymerized resilient silicone soft lining material (Acrostone, Soft linermaterial, Egypt) was used to mimic resilient edentulous ridge mucosa.

Maxillary experimental overdentures were constructed and connected to the implant with the milled bar attachments. In the group (I) the bar abutments were threaded to the internal hex of the implants then scan body (Amann Girrbach, GmbH, Germany) fixed to the implant to be used as a reference for CAD-CAM as a bar abutment. The plastic pattern of milled bar was designed by using software (2mm width, 3mm height and 65mm length). After that 3D printing of the plastic pattern by using special type of acrylic resin (GC AMERICA INC. ALSIP, IL 60803), A space of 1.5mm between the bar and the mucosa was preserved. then the Titanium disk was milled to produce Titanium milled bar by the add of milling machine (Milling unit BF 2, Bredent, GmbH&Co, KG, German).

Fabrication of the overdenture attachment.

For the construction of the milled bar, the bar abutments were threaded to the internal hex of the implants then scan body CAD-CAM (Amann Girrbach, GmbH, Germany) fixed to the implant to be used as a reference as a bar abutment. The bar was designed with distal cantilever added distal to the premolar implants. The plastic pattern of milled bar was designed by using software. After that 3D printing of the plastic pattern by using special type of acrylic resin (GC AMERICA INC. ALSIP, IL 60803), the plastic pattern was checked for passive fit without interference. the plastic pattern was ascended by using software and then the Titanium disk was milled to produce Titanium milled bar (2mm width, 3mm height and 65mm length) by the aid of milling machine (Milling unit BF 2, Bredent, GmbH&Co, KG, German)**.** The Titanium bar was checked for passive fit without interference and then finished and polished. Finally, the bar plastic pattern housing was constructed by using acrylic resin the bar plastic pattern housing was constructed by using acrylic resin The milled bar was sprayed with scannable material to be scanned design the metal housing then. then the plastic pattern of the housing was 3D printing, and checked for passive fit without interference. finally, a titanium housing was milled by CAM milling machine. and checked on the master cast to be ensure that there is no interference by the aid of fit checker then finished and polished**.** (Fig1, d)

Construction of the overdenture:

To make a mold of the acrylic cast by using of a silicon duplicating material then the mold was poured by using investment material to get two casts, the first one a refractory cast for construction of the metal framework, the second cast was a dental stone cast for construction of the acrylic part of the overdenture. A meshwork of a readymade wax pattern was added on the bar sites of refractory cast then the wax pattern was sprue, invested and casted in cobalt chromium. The metal framework was removed and finished and polished. And it was checked on the stone cast and acrylic model for proper seating.

the overdenture constructed by the wax occlusion rim on metallic framework without any denture teeth with occlusal plane parallel to the crest of the ridge. The occlusion rim was flasked, wax eliminated, packed with heat-cured acrylic resin and polymerized according to the manufacturer's instructions to get maxillary acrylic record base. The record bases were finished and polished. The experimental overdenture was connected to the implant using either milled bar or Locator attachments.

Strain measurement:

Strain gauges' fixation:

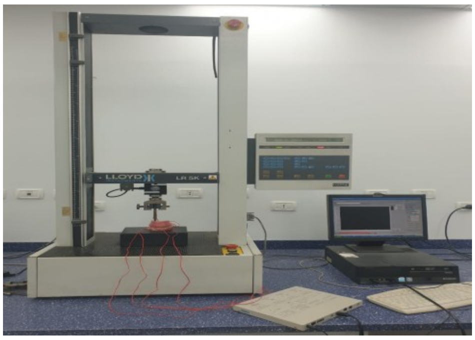
The strain gauges (Kyowa electronic instrument CO.LTD Tokyo, Japan). Type KFG-1-120-C1-11L1M2R. used had the following specifications: gauge factor (24°C,50%RH) =2.13±1.0%, gauge Length =1 mm, gauge Resistance (24°C,50%RH) = 120.4±0.4Ω, adaptable thermal expansion=11.7 PPM / C, temperature coefficient of gauge factor= +0.008%/°C, lot no=Y4537S and Batch = 362A.Because it is feasible to use the strains occurring on the bone surface as an indicator of the moments arising, strain gauges were placed directly on the surface of the acrylic resin.

A 5 mm of the soft-liner mucosal simulation was removed from the acrylic resin at buccal, and palatal surface around each implant.to permit bonding of strain gages to the acrylic resin. The acrylic resin surfaces were flattened with a fissure bur, as recommended by the manufacturer. All prepared surfaces were smoothened with fine grit sandpaper to obtain a surface texture suitable for strain gauge bonding to avoid any incremental apparent strain.Two linear strain gauges were bonded to the buccal, and palatal surfaces around each implant at the right side (loading side) and the left side (non-loading side). all strain gauges were cemented using cyanoacrylate adhesive (CC-33A, EP-34B, KYOWA adhesive electronic instruments). The strain gauges were held in site for five minutes using Teflon sheets supplied with the gauges as recommended by the manufacturer to avoid adherence of the cement to the hands.

The terminals of the 8 strain gauges' wires were connected to a digital multichannel strain meter (Tinsley and Co. Ltd., Werndee Hall, London, H. Model 8692) that connected to a compatible computer containing the meter control software (Kyowa PCD 300A).

Strain gauge calibration:

Before strain measurements, a calibration experiment to the gauges was made to assess the repeatability of force measurements and the linearity of the gauges.A cyclic load ranging from 0 to 100N was applied 5 times on the occlusal surface of maxillary denture using the loading device to age the gauges. The simulation model was attached to a loading apparatus with the occlusal plane of the overdenture in a horizontal position. A universal testing loading device(Lloyd instruments Ltd., Hampshire, UK) **(fig 1)** which apply the load every time in the same magnitude and direction was used to apply a vertical static load (unilateral and bilateral).The right side of the overdenture (contralateral to the strain gauges) was the loading side, while the left side (contralateral to the strain gauges) was the non- loading side. During unilateral load application, the point of load application was selected at the site of cusp tip of canine and central occlusal fossa of the second premolar marked in the acrylic resin surface of record block. This was done for reproducibility and accommodation of the tip of the loading pin in the same location to prevent slippage of the pin.during bilateral load application, a metal bar was positioned between the right and left denture bases at the level of the occlusal plane in the region of the palatal cusp of the second premolar. The forces were delivered to the center of the metal bar using the loading pin (applicator) of the loading device.All measurements were repeated 5 times for each experimental denture, allowing at least 5 minutes for recovery and for heat dissipation.


(Fig 1) Universal loading device

Statistical analysis:

Shapiro-Wilk test was used to identify the normal distribution of data. The data was non-parametric and violate the normal distribution. The descriptive statistics of peri-implant strain values included mean, standard deviation, median, minimum, and maximum. Mann-Whitney test was used to compare recorded microstrain values between the groups and implant positions (during bilateral loading). P value is significant if it was less than .05 at confidence interval 95%. The SPSS statistical package for social science version 22 (SPSS Inc., Chicago, IL, USA) was used for data analysis

Results:

Descriptive statistics

For bilateral load applications, strain values showed a highly significant difference between groups. The highest strain values were recorded in group I and the lowest strain values were recorded in group II and the same result in unilateral loading. (Table 1,2 and 3)

Analytical statistics

During bilateral load applications, there was no significant difference in peri-implant strains between implant positions for both groups (P>.05). (Table 4)

During unilateral premolar loading There was a significant difference in peri-implant strains between implant positions for milled bar (P<.001) and for milled bar with attachment (P=.003). during unilateral canine loading There was a significant difference in peri-implant strains between implant positions for milled bar (P<.001) and for milled bar with attachment (P=.020).(Table 5 and 6)

Table 1. Descriptive statistics of Microstrain at different implant positions of groups during bilateral loading:

		Canine implants	**Premolar implants**
Milled bar	**Mean**	63.25	34.50
	St deviation	42.56	3.94
	Median	57.50	35.00
	Minimum	15.00	30.00
	Maximum	130.00	45.00

Table 2. Descriptive statistics of Microstrain at different implant positions of groups during unilateral premolar loading:

		Canine implants on loading side	**Canine implants on non-loading side**	**Premolar implants on loading side**	**Premolar implants on non-loading side**
Milled bar	Mean	186.00	27.00	129.50	47.00
	St deviation	14.10	19.75	16.74	33.76
	Median	182.50	45.00	22.50	125.00
	Minimum	165.00	15.00	5.00	110.00
	Maximum	210.00	80.00	55.00	155.00

Table 3. Descriptive statistics of Microstrain at different implant positions of groups during unilateral canine loading:

		Canine implants on loading side	**Canine implants on non-loading side**	**Premolar implants on loading side**	**Premolar implants on non-loading side**
Milled bar	Mean	207.00	73.50	104.50	95.50
	St deviation	37.06	46.51	49.13	41.70
	Median	195.00	100.00	107.50	72.50
	Minimum	170.00	20.00	55.00	30.00
	Maximum	265.00	140.00	155.00	115.00

Table 4. Comparison of Microstrain between groups and implant positions during bilateral loading:

		Canine implants	***Premolar implants***
Milled bar	***Median***	57.00	35.50
	Minimum	30.00	30.00
	Maximum	45.00	45.00
Mann-Whitney test P value		0.009*	.0.005*

Table 5. Comparison of Microstrain between groups and implant positions during unilateral premolar loading

		Canine implants on loading side	Canine implants on non-loading side	Premolar implants on loading side	Premolar implants on non-loading side
Milled bar	***Median***	182.50a	45.00b	125.00a	35.00b
	Minimum	165.00	15.00	110.00	15.00
	Maximum	210.00	80.00	155.00	65.00
Mann-Whitney test P value		<.001*	<.001*	.049*	.001*

*p is significant at 5%. Different letters in the same column indicate significant difference in microstrains between each 2 implant positions. The same letters indicate non-significant difference between implant positions

Table 6. Comparison of Microstrain between groups and implant positions during unilateral canine loading

		Canine implants on loading side	Canine implants on non-loading side	Premolar implants on loading side	Premolar implants on non-loading side
Milled bar	***Median***	195.00a	72.50a,b	107.50b	100.00b
	Minimum	170.00	30.00	55.00	20.00
	Maximum	265.00	115.00	155.00	140.00
Mann-Whitney test P value		<.001*	1.00	.049*	.001*

*p is significant at 5%. Different letters in the same column indicate significant difference in microstrains between each 2 implant positions. The same letters indicate non-significant difference between implant positions

Discussion

The laboratory studies are preferred than the clinical studies for evaluating introduced stresses in the bone around implants due to the fact that an in vivo test cannot be repeated under the same conditions. In a clinical situation, it wouldn't be possible to control factors such as implant angulations, bone density, direction and amplitude of forces, and resilience of the soft tissue on the ridge. However, the major limitation of in vitro biomechanical stress analysis is the necessity to drive certain assumptions or to use materials that frequently don't simulate the complex nature of living tissues [5].

The measurements from the CBCT to simulation of patient reality. the CBCT are routinely accurate throughout the mandible and maxilla makes this an accurate imaging modality for planning implant placement. The advent of cone beams computerized tomography (CBCT) has enhanced the development of 3D printing in dentistry. This **led** to more accurate simulation of the positioning of implants [6]. As the same as the construction of a STereoLithographic surgical stent, the CBCT of the patient was converted to an STL file software to be used by a 3d printing machine to construct an exact replica of the patient's maxillary arch. the implants in Canine and second premolar areas were chosen to provide quadrilateral support compared to the linear designs at the anterior area of maxilla [7]. The premolar area has been more favorable in stress transfer to the underlying bone than a concentrated of implants in the anterior area.[8] Also, this design ensures that anterior-posterior spread of the prosthesis was favorable.

the simulation of mucosal masticatory resiliency which overdenture rests is very important of overdenture There is many an in vitro strain gauge studies reported there is [9], 2mm of thickness of silicone soft lining material was used to simulate masticatory mucosa for all parts of the edentulous areas. Overdenture may contact with the mucosa and so may affect the way of overdenture disconnection from attachments during anterior, posterior and lateral dislodging.[10-11]

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Strain gauges were bonded to the crest of the ridge buccal and palatal around the implants. This was done because resorption and bone loss as a result of peri-implant stresses usually initiated at the alveolar crest around the implant's neck. The occlusal forces are distributed primarily to the crestal bone, rather than evenly throughout the entire surface area of the implant interface[12]. The load was applied unilaterally to reproduce mastication on the preferred chewing side of the patient.[13]

For all groups During unilateral canine loading Comparison of recorded macrostrain values between groups for canine and premolar implants at loading and non-loading sides, milled bar showed significant higher strain than milled bar with attachment.

the highest stain was noted with Canine implants on loading side, followed by Premolar implants on loading side, then Canine implants on non-loading side and the lowest strain was observed with Premolar implants on non-loading side, Similarly, other finite element analysis studies[14,15]found that tilted distal implants, rigidly splinted with a fixed prosthesis decreased peri-implant bone stresses as compared to vertical implants. In line with this finding, Wismeijer et[16]a noted that when 4 implants are connected to each other's with rigid bar superstructures, there was significantly more bone loss and unfavorable strain around the central 2 implants in comparison with the posterior ones. The results of this study are only descriptive because the physical properties of acrylic resins do not simulate the complex nature of living bone regarding mechano-biology and osseointegration.[7] Further studies may be helpful to evaluate the load transfer characteristics with different load directions applied to vertically oriented and inclined implants[17].

Conclusion:

Within the limitation of this *in vitro* strain gauge analysis, that stresses are higher at the inserted implant at the canine area than those inserted in premolar area in milled bar attachment cases.

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