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EFFECT OF SPLINTING USING WELDING TECHNIQUE IN STRAIN DEVELOPED ON THE SUPPORTING STRUCTURES IN [ALL-ON-FOUR]

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ABSTRACT

Introduction: All-on-Four used with anatomical limitations in the atrophied edentulous mandible. All on four requires rigid splinting by metal bar like welding for better distribution of load around implants.

The aim of this study: to evaluate the effect of splinting implants in All-on-four design using welding technique on strain induced from vertical loads on both axial & tilted implants

Materials and methods: lower completely edentulous 3d printed model with all on 4 implants was fabricated. Two printed lower complete dentures were used one in group (A) where provisional all on 4 prosthesis was fabricated by conventional pick up technique engaging four titanium sleeves screwed to the four multi-unit abutments. The second printed lower complete denture was used in group (B) to fabricated splinted welded titanium bar provisional all on 4 prosthesis using same pick up technique as in group (A).load was applied to the two provisional prosthesis and strains were recorded. Data were collected & statistically analysed to compare both groups by independent t-test, the p-value was considered significant at the level of <0.05.

Results: The two studied groups showed statistically significant where strain induced around all on 4 implants were reduced in group (B) in compared to group(A)

Conclusion: With in the limitation of this study splinting all on four implants in provisional prosthesis reduced stresses and strains around implants in compared to conventional non splinting provisional prosthesis.

KEY WORDS: Splinting, all on four, welding mandible

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INTRODUCTION

Dental implants are one of the favourable treatment options in edentulous patients specially in mandibular arch. Anatomical landmarks like superior position of the inferior alveolar canal and extensive bone resorption with poor bone quality limit the use of the dental implants.[1-4]

The fixed hybrid prosthesis with all on 4 concept in severely atrophied mandible was first applied by Malo in 2003 where multi-unit abutments were used on total four implants where two anterior vertically placed implants and two posteriorly placed implants with 15-45° angle with immediate making and loading of temporary prostheses (in the postoperative 8--48 h) and permanent fixed prostheses after the 3-month period. [1,5-7]

The use of tilted distal implants is much better biomechanically than distal cantilever units. Tilting improves antero-posterior spread of implants and reduces the length of cantilevers resulting in a more stable prosthesis. Marginal bone height of implants is maintained with rigid prosthesis. [8-14]

In immediately loaded implants of completely edentulous cases, the most common post-surgical complication following the surgery is the fracture of the provisional acrylic prosthesis, with rates ranging from 4.17% to 41%. Most of these fractures occur because poly methyl methacrylate material has low rigidity to withstand an extended period of heavy occlusal loads.[15-16]

Immediate loading concept in implant prosthesis, we use either semi-rigid splinting with acrylic resin or rigid splinting by a metal bar.Splinting (rigid or non-rigid) has been indicated to prevent axial rotation and movement of implants submitted to immediate loading[17-18]

In 2006 Degidi introduced a new protocol called "syncrystallization" It is a rigid temporization of immediately loaded multiple implants with metal reinforced acrylic resin restorations. A prefabricated titanium bar is welded to implant abutments directly in the oral cavity. [19] Intraoral Welding devices are based on the resistance spot welding principle. They provide a stable and passively fitting framework for temporary or durable prostheses for immediate restorations suitable for immediate or late loading on the same day of surgery. [20]

MATERIALS AND METHODS:

Fabrication of lower completely edentulous 3d model

An educational lower completely edentulous cast was scanned by desktop scanner (Ds mizar, egsolution, Italy) to produce STL file of the cast to modify it virtually for the implants designing and space for mucosa simulating tissue.

All on 4 implants virtual design in 3d model

Four implants' sites were designed virtually at equidistance from the midline following all on four protocol where two anterior implants were placed vertically and two posterior implants were placed with 30 degree angulation.

Mucosa simulating tissue virtual design

Virtually 2mm thickness were cut back from the 3d model to create space for the mucosa simulating tissue to be placed on the printed 3D model by mucosa key index. Mucosa key index was designed on the virtual 3d model with enough space for placement of the mucosa simulating tissue equivalent to the amount of cut back that was done on the virtual 3D model.

Printing of the modified 3D model and all on 4 implant insertion

The modified 3D model STL file was printed using additive 3D printer (Epax3d printer, china). Four implants were installed and cemented in their previously digitally planned sites in the printed 3D model. Two straight multi-unit abutments were screwed to the two anteriorly vertically placed implants while 30 degree angled multiunit abutments were screwed to the two posteriorly 30 degree angled implants. Mucosa key index was printed and used to inject mucosa simulating tissue material (Multisil- Mask, Bredent, Sedan, Germany) on the printed 3d model with installed all on 4 implants. **Fig (1)**

Fig. (1) 3D printed cast with installed all on 4 implants and mucosa simulating material

Digital fabrication of lower complete denture

Data acquisition

The 3D model with the installed all on 4 implants with their multiunit abutments was scanned on desktop scanner to have a new STL file to design lower complete denture.

Designing of lower complete denture

Exocad soft ware was used to design parts of lower complete denture, the denture base and the artificial teeth. Denture base was fabricated by printing manufacturing technique using PMMA printing material (Next Dent model resin, Vertex Dental B.V., Netherlands).

Lower complete denture base virtual designing

Mandibular landmarks and limiting structures were traced and marked on the 3D model which included position of the buccal frenum, lingual frenum, retromolar pad and the first molars position. Denture base borders, thickness of 2mm, path of insertion and removal were determined virtually. **fig (2)**

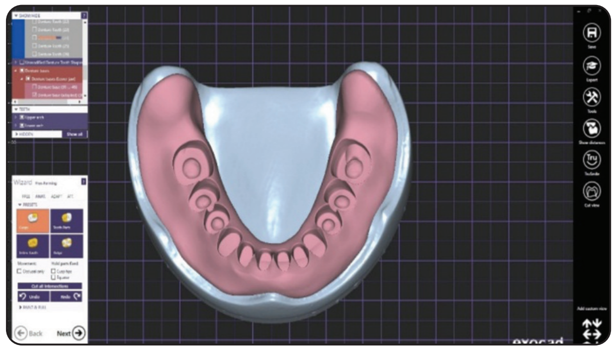

Fig. (2) Designing of lower complete denture base on Exocad software

Artificial teeth virtual setting

Artificial teeth setting was selected from Exocad library and once their design was finalized STl file was saved and exported for lower complete denture digitally fabricated by printing manufacturing technique.

Lower complete denture printing manufacturing

Two lower complete denture bases were printed from pink denture base printing resin material (Next Dent model resin, Vertex Dental B.V., Netherlands.) at the same printing cycle **fig (3)**. The artificial teeth were printed from white printing resin material (Next Dent model resin, Vertex Dental B.V., Netherlands).

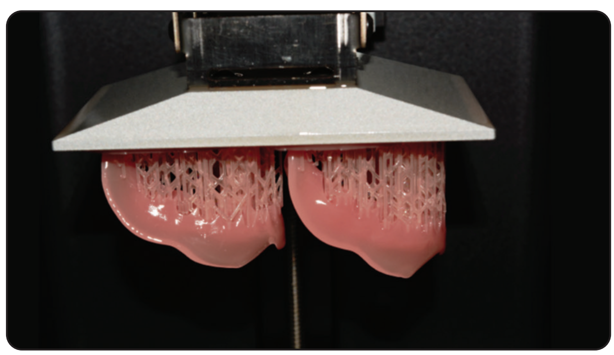

Fig. (3) Printing of two dentures bases at same cycle

Printed denture bases were finished, cleaned, and dried in curing unit (Brelux power unit 2, Bredent, UK) for 90 seconds. Printed artificial teeth were bonded in their crossponding recess with dual hardener composite (DTK-Kleber, Bredent, Sedan, Germany). Both lower dentures were hollowed crossponding to the replanned sites of all on 4 implants. **fig (4)**

Fig. (4) Hollowed lower printed complete denture corresponding to the area of the planned implants positions

Grouping of the printed lower complete dentures supported by all on 4 implants

Group A:

Four titanium (Ti) sleeves were screwed to the four multiunit abutments. The hollowed printed lower complete denture was seated on the four Ti sleeves to check for enough hollowing around them with no interference. Ti sleeves were shortened to the level of occlusal plane of the lower printed complete denture. Pick up was done using self-cured acrylic resin material (cold cure, huge, china.)after blocking screw access in Ti sleeves with teflon. After total set of pick up material four Ti sleeves were unscrewed. The picked up printed lower complete denture was converted into provisional acrylic all on 4 prosthesis after shorting denture flanges and polishing the fitting surface to have convex polished surface.

Group B:

The four Ti sleeves were screwed in same manner as in group A to the multi-unit abutments. Welding of the four Ti sleeves was done using Ti welding bar of 2 mm diameter which was passively adapted to the lingual side of the four Ti sleeves **fig (5)**. The welding protocol was followed according to Degidi et al using intra oral welding unit (JD Weld, J Dental Care, Modena, Italy).[19]

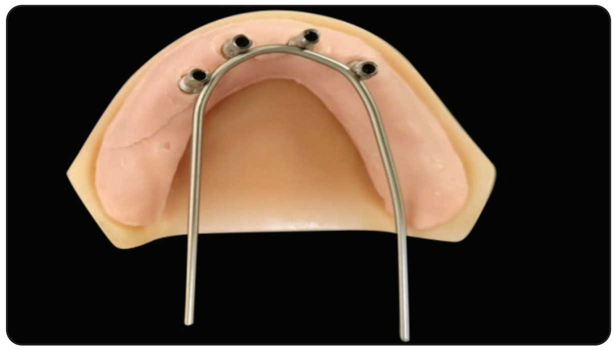

Fig. (5) Ti welded bar adapted lingually to the Ti sleeves

Intra oral welding protocol included three main stages, the first one is preparation by using welding pincers and copper electrodes at the extremity of the pincers with firm pressure at the parts to be welded. The second stage of welding aimed to provide electric current to the copper electrodes to raise the temperature of the two titanium components to a fusion point. the final third stage is the cooling stage that occurred due to favourable thermal conductivity property of the titanium parts and the copper electrode which was important to have no damage to the surrounding parts of the prosthesis.

Welded framework of Ti sleeves with Ti bar was checked for its passivity by sheffied 1 screw test followed by sand blasting. The printed lower complete denture was relieved over the welded Ti sleeves with Ti bar by creating a trough the pick up was done by same manner as in group A. Conversion of the picked up lower printed complete denture into a provisional acrylic all on 4 prosthesis with welded frame work of Ti sleeves with Ti bar was done in same manner as in group A. **fig(6)**

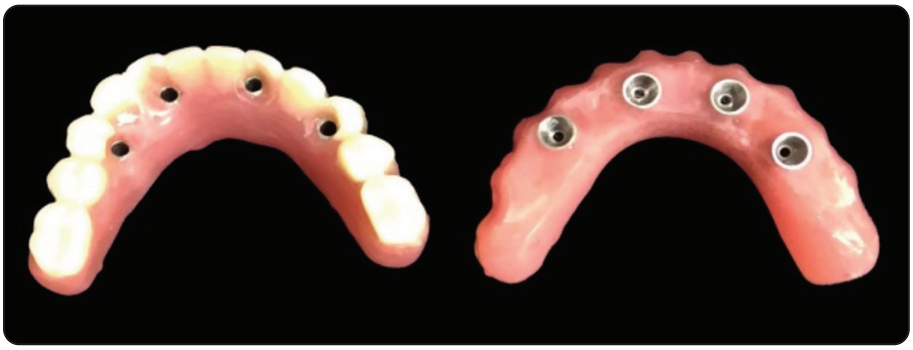

Fig. (6) provisional acrylic all on 4 prosthesis

Stress analysis and load application

Strain gauge installation

Stress analysis was done for both groups using strain gauge (strain gauge, Kyowa, Japan) of 1 mm length and gauge resistance 0.4Ω. provisional prosthesis was unscrewed from the implants and mucosa simulating material was removed from the cast and strain gauges were cemented to the mesial and distal aspect with 1mm from each implant by delicate layer of adhesive cement.

The terminals of the strain gauge wires were inserted into four channels strain meter (Kyowa, kyowa Electronic Instruments Co, Ltd,Tokyo, Japan) to measure the micro strains induced by the applied load.

Load application

Universal testing machine (Lloyd LRX; Lloyd Instruments Ltd., Fareham, UK)(was used for applying vertical load either unilateral or bilateral for both provisional prosthesis in both groups. The 3D printed model with the provisional all on 4 prosthesis screwed to the implants was placed on the lower metal plate of the universal testing machine for calibration 10-60N load was applied.

Unilateral load was applied using I bar shaped load applicator on the left side representing working side at the central groove of the first premolar. The strain was recorded at the working and balancing side. **fig(7)**

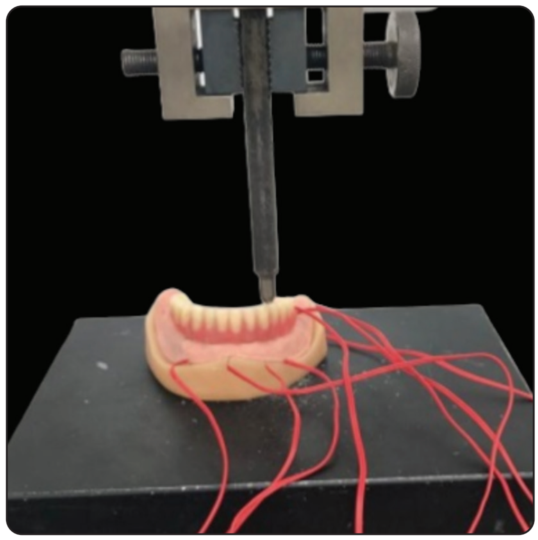

Fig. (7) Load application unilaterally by I bar load applicator

Bilateral load was applied using T shaped load applicator bar at lateral incisors area first then at the first premolars area. The load was applied 0-100N at a constant rate of 1 mm/sec. The strains at four distally placed strain gauges were first recorded followed by the strain records at the other four strain gauges mesially placed to the four implants.

Statistical Analysis

The mean and standard deviation values were calculated for the two groups in this study. Data were explored for normality using Kolmogorov- Smirnov and Shapiro-Wilk tests, data showed normally distribution. The comparison between two groups with quantitative data and parametric distribution were done by using independent t-test. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

RESULTS

When unilateral load directed to the first premolar position. The loaded side, in group A, the mean value was (-31.10) with standard deviation (5.80). While for the loaded side of group B, the mean value was (-63.76) with standard deviation (7.46). When comparing the two groups the calculated amount of compressive stresses induced were statistically significant P< 0.05 where the recorded P value was (0.0001). For the unloaded side, in group A, the mean value was (-12.08) with standard deviation (2.04). While for the unloaded side of group B, the mean value was (-24.81) with standard deviation (4.82). When comparing the two groups the amount of compressive stresses induced were statistically significant P< 0.05 where the recorded P value was (0.0001). **tab (1)**

TABLE (1) Mean and standard deviation of loaded side and unloaded side when forces directed on 1st premolar in unilateral compression in group A and B and comparison between them.

Loading direction	Loading side	GA		GB		P value
		M	SD	M	SD	
1st premolar	Loaded	-31.10	5.80	-63.76	7.46	<0.0001*
	Unloaded	-12.08	2.04	-24.81	4.82	<0.0001*

When unilateral load directed to the first premolar position. The loaded side, in group A, the mean value was (100.21) with standard deviation (8.29). While for the loaded side of group B, the mean value was (43.43) with standard deviation (5.66). When comparing the two groups the calculated amount of tension stresses induced were statistically significant P< 0.05 where the recorded P value was (0.0001). For the unloaded side, in group A, the mean value was (62.52) with standard deviation (6.68). While for the unloaded side of group B, the mean value was (58.86) with standard deviation (11.21). When comparing the two groups the amount of tension stresses induced were statistically insignificant P>0.05. where the recorded P value was (0.47) **tab (2)**

TABLE (2) Mean and standard deviation of loaded side and unloaded side when forces directed on 1st premolar in unilateral tension in group A and B and comparison between them.

Loading direction	Loading side	GA		GB		P value
		M	SD	M	SD	
1st premolar	Loaded	100.21	8.29	43.43	5.66	<0.0001*
	Unloaded	62.52	6.68	58.86	11.21	0.47

When forces directed to the first premolars position bilaterally. For the straight implants, in group A, the mean value was found to be (-18.50) with standard deviation (1.95). While in group B, the mean value of the straight implants was (-38.33) with standard deviation (7.45). When comparing the two groups the amount of compressive stresses induced were statistically significant as P< 0.05. where the recorded P value was (0.0001). For the angulated (peripheral) implants, in group A, the mean value was (-24.67) with standard deviation (5.90). While in group B, the mean value of the peripheral implants was (-50.24) with standard deviation (4.84). When comparing the two groups the amount of compression stresses induced were statistically significant as P< 0.05. The recorded P value was (0.0001). **tab (3)**

When forces directed to the first premolars position bilaterally. For the straight implants, in group A, the mean value was (105.89) with standard deviation (7.98). While in group B, the mean value of the straight implants was (43.28) with standard deviation (9.87).

When comparing the two groups the amount of tension stresses induced were statistically significant as P<0.05. The recorded P value was (0.0001). For the angulated implants, in group A, the mean value was (56.84) with standard deviation (6.99). While in group B, the mean value of the angled implants was (59.01) and the standard deviation was (7.00). When comparing the two groups the amount of tension stresses induced were statistically insignificant as P>0.05. The recorded P value was (0.52). **tab(4)**

TABLE (3): Mean and standard deviation of straight and angulated implants when forces directed on the 1st premolar in bilateral compression of group A and B and comparison between them.

Forces direction	Implant	Group A		Group B		P value
		M	SD	M	SD	
1st premolar	Straight implant	-18.50	1.95	-38.33	7.45	<0.0001*
	Angulated implant	-24.67	5.90	-50.24	4.84	<0.0001*

TABLE (4) Mean and standard deviation of straight and angulated implants when forces directed on the 1st premolar in bilateral tension of group A and B and comparison between them.

Forces direction	Implant	Group A		Group B		P value
		M	SD	M	SD	
1st premolar	Straight implant	105.89	7.98	43.28	9.87	<0.0001*
	Angulated implant	56.84	6.99	59.01	7.00	0.52

DISCUSSION

The biomechanical design of complete mandibular dentures are more challengeable than maxillary dentures where the supportive bearing area in the mandible is smaller in compare to the maxilla [21].

Digital technology application in complete denture fabrication gave many advantages than conventional manner where elimination of impression step, eliminate the facture risk of final denture especially interim ones supported by implants as in all on 4 protocol where printed or milled poly-methyl methacrylate (PMMA). provisional prosthesis showed more durability [22]

Additive rapid pro typing fabrication technology showed speed of production with high accuracy where precision of treatment plan details like the dimensions, the directions and the exact locations of each implant bed can be determined. [23,24]

All on four implant protocol for atrophied arches gives many advantages like avoiding bone grafting, reducing the posterior cantilever, easier to clean, immediate prosthesis with accepted esthetics and function. [25]

From a biomechanical point of view, splinted all on 4 implants with welding technique has demonstrated many advantages, decreasing destructive loads specially around distally tilted implants and welding procedure can be performed directly in the mouth so can eliminate the possibility of errors or distortions due to impressions which affected the passive fit of the prosthesis on implants. [26]

Study results showed significant difference between Group(B) and Group (A) where a significant reduction of strain in Group B could be detected when vertical unilateral and bilateral load were applied.[27] when forces were applied to the prosthesis in group (A) harmful stresses rapidly propagate around implants while in group (B) Splinting implants with welding using Ti bar decreased the risk of overload to each implant because of the greater surface area and improved biomechanical distribution. Results in this study were coinciding with other researches findings where distal angulated implants which splinted in a fixed restoration did not increase the stress in the marginal bone in compare to axial implants [28-31]

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