Comparison between linear and curved arrangement of Telescopic attachment used for 4 implants mandibular overdenture: A study of clinical deformity of denture base

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Abstract:

Objective: The aim of this study was clinical evaluation of stresses developed in complete mandibular overdenture assisted by four implants using telescopic attachment placed in curved or linear configurations. **Materials and Methods:** Twelve completely edentulous participants were selected for the study and each patient received four implants. All patients were into 2 equal groups regarding implants position: The first group (Linear design): The four implants were installed at lateral incisor and canine areas. The second group (Curved design): the four implants were installed bilaterally in the interforaminal region of the mandible (at canine and second premolar areas). The implants were connected to the overdentures with resilient telescopic attachments. Eight strain-gauges were adhered to the polished surface of each denture using a special adhesive. The gauges were aligned horizontally parallel opposite to each attachment [1] and on lingual and buccal polished surface related to molar area[2]. Three months after wearing implant overdenture, strain registrations were performed during clenching without food. Strain gauges and multichannel strain-meter were used to compare denture strains between groups and channels. **Results:** For all channels, linear group recorded significant higher microstrains than curved group. For both groups there was a significant difference in microstrains between channels. **Conclusion:** Within the limitation of this short-term cross over trial, curved arrangement for mandibular implant assisted overdentures is recommended than linear arrangement as it reduced denture base strains and deformation during maximum voluntary clenching.

Introduction:

The conventional tissue-supported complete denture was considered the treatment of, some patients facing difficulties to adapt with choice for completely edentulous patients. However it, even if the dentures are prosthodontically acceptable.[3] This is a result of patients becoming edentulous at an older age when they are generally less able to adapt to the limitations of complete dentures. Added to this, are higher expectations of dental treatment by patients.[4]

Implant supported overdentures have been proven by many studies to be an effective treatment option for restoring completely edentulous arches, with high success rates ranging from 94% to 100%.[5,6] The clinical outcome of implant-supported overdentures is very successful in the mandible under delayed and immediate loading conditions and two implants are considered the first and standard treatment option.[7,8]

Various attachments have been proposed for connecting overdentures to underlying implants. These Attachments are compatible with most of the implant systems currently available. They are divided into 2 major categories: splinted type (bar attachment) and stud type (solitary) attachments like (telescopic, ball/socket, locators and magnets), although attachments may be classified as resilient joints (connectors), when movements between parts of the attachment allowed, or rigid joints, when such movements not allowed.[9]

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Telescopic crown attachments are also referred to as crown-and Sleeve coping, double crown, and konuskrone, which is a German description of a cone-shaped abutment.[10] They are consisted of inner coping, or a primary telescopic crown cemented to a natural tooth abutment, or a screw-retained primary telescopic abutment and an outer secondary telescopic crown attached to a removable dental prosthesis (RDP). Retention is achieved by the fitting and friction between the outer and inner crowns.[11]

The telescopic attachments are either rigid or non-rigid (resilient). Rigid telescopic crowns have a definite end position between inner and outer copings. Such telescopes include parallel-wall crowns and conical crowns, which achieve retention by friction and wedging. Non rigid telescopes have no define end position. These telescopes include crowns with tiny spaces between the copings and crowns with additional retention elements.[12,13] Since 1989 non-rigid telescopic attachment have been used to support a removable overdenture for the treatment of completely edentulous patients. So, it has been over years of good clinical experience.[13]

The materials used for manufacturing implant abutments should have desirable biological, mechanical, and esthetic properties. Titanium, gold and zirconium are the most well-known materials used in prefabricated abutments.[14] Titanium is considered the gold standard and is most frequently used, although it has several disadvantages, such as grayish color, corrosion susceptibility and oversensitivity reactions.[15]

With the evolution of the (CAD/CAM) technology, customized abutments are now easier to produce. The CAD/CAM process can optimally control the geometry of the abutment and adjust it to the optimum design to overcome the drawbacks of prefabricated abutments and providing the titanium-to-titanium contact for a better fit. The material property of a titanium abutment is the same as that of a titanium dental implant. Therefore, a titanium abutment has less abrasion and high resistance to fracture in long-term use.[16,17]

The ability of the denture base to resist deformation encountered from masticatory loads is an important factor in the prevention of denture fracture. [18]Fracture of overdenture bases tend to occur more frequently in areas adjacent to the implant(s) retaining a mandibular overdenture due to inadequate thickness of acrylic resin around the attachments.[19]

The 2-mm denture base thickness had sufficient fracture strength without reinforcement and a positive relationship between acrylic resin thickness and fracture resistance was found.[20]

Strain gauge analysis has been used extensively in stress analysis studies with different prosthodontics appliance designs both in-vitro and invivo. This technique is one of the common methods used for dental stress analysis that can overcome many shortcomings of the application of other methods.[21]

Strain gauges are constructed so that the strains in the body to which they attached are accompanied by a proportional change in the ohmic resistance of the gauge. These changes are registered as strain indices.[22]

They are widely used in in-vitro studies movements of patient, movement of the transmission wire and presence of saliva make it difficult to use strain gauge in-vivo studies.[23]

The aim of this study was to compare the effect of the curved and linear implant arrangements on strain developed around four implants supporting a mandibular overdenture with telescopic attachment. The null hypothesis is that there would be no difference between the curved and linear designs.

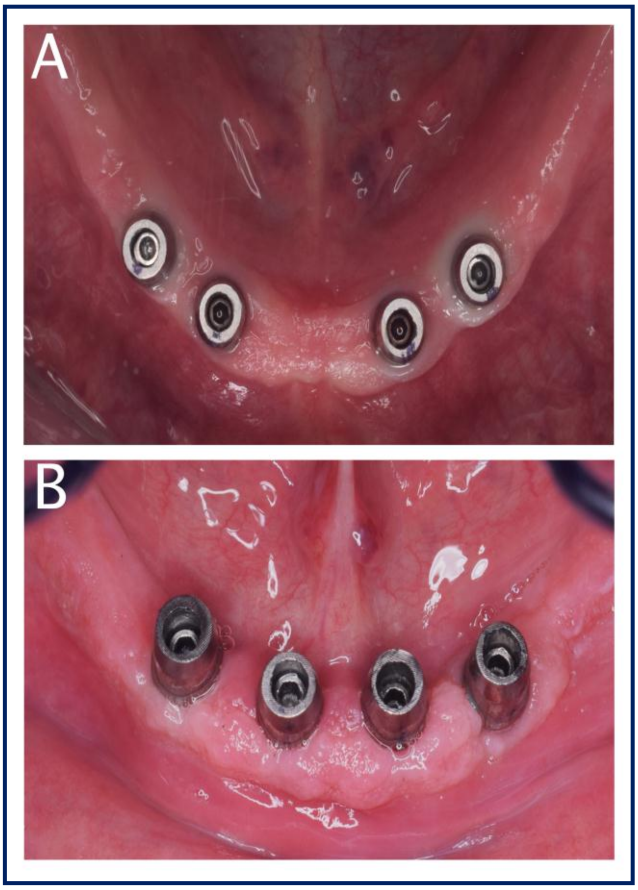
Materials and Methods:

Twelve completely edentulous healthy patients were selected for this study from the Department of Removable Prosthodontics, Faculty of Dentistry, Mansoura University. All patients expressed the interest to participate in the implant assisted overdenture study. They were thoroughly informed about the full details about surgical procedures. All signed the consent form of ethic committee in Faculty of Dentistry, Mansoura University No (M16080120).

The inclusion criteria are;1) Free from any systemic disease that may interfere with proper Osseo-integration of implants, which will be assessed by thorough medical investigations,2) Patients having completely edentulous maxilla and mandible for at least 6 month after last extraction,3) Having normal maxilla mandibular relationship with adequate inter arch space which was measured by tentative jaw relation,4) sufficient residual alveolar ridge,5) Proper oral hygiene.

The patient who had one of the following conditions was excluded from the study; 1) Local or general contraindication for surgical procedures, 2) Patients with TMJ disorders or poor neuromuscular co-ordination or parafunctional habits, 3) Severe inter-maxillary skeletal discrepancy or limited inter arch space, 4) Heavy smokers, 5) History of chemotherapy or radiation therapy to the head and neck area, 6) Uncooperative patients (those who didn't follow the instructions or didn't attend the appointments). All patients informed about benefits and risks of this treatment plan and that this treatment was accomplished in a clinical research protocol. All signed the consent form of ethic committee in Faculty of Dentistry, Mansoura University.

The scheduled treatment plane for all patients was to receive four implant retained complete mandibular overdenture with telescopic attachment opposed by conventional maxillary complete denture. Patients classified into 2 equal groups regarding implants arrangements; The first group (Linear design); the 4 implants will be installed at lateral incisor and canine areas ,The second group (Curved design) ;the 4 implant installed bilaterally in the inter-foraminal region of the mandible (at canine and 2nd premolar areas). (Figure 1)



I. Surgical and prosthetic interventions

After Fabrication of maxillary and mandibular conventional complete dentures, Putty rubber base bite index was made between the upper and lower complete dentures in order to stabilize and maintain denture in a fixed position during the subsequent steps. The mandibular denture was duplicated into clear acrylic resin with radiopaque markers attached to the duplicate denture at proposed implant positions. CBCT was performed to evaluate implant sites, select the proper implant lengths and widths. The duplicated denture was double scanned using cone beam computed tomography. Superimposition of the two radiographs guided by the radiopaque points and fabrication of the surgical guide, using stereolithography. After that, metal sleeves were placed at the planned position in the stent and cemented by visible light cured resin.

The stereolithographic surgical guide was placed in the patient mouth then was asked to close firmly on the rubber base Index, after that the three stabilization pins were used for fixation. tissue punch was used to cut through the soft tissue down to the crest of the ridge then four osteo-integrated implants (13mm length x3.8mm diameter) (Dentium, South Korea) were inserted in two different designs (linear & curved) arrangements using two stage surgical protocol. The denture was relieved and relined with soft liner (mollosil®,Detax, Germany).

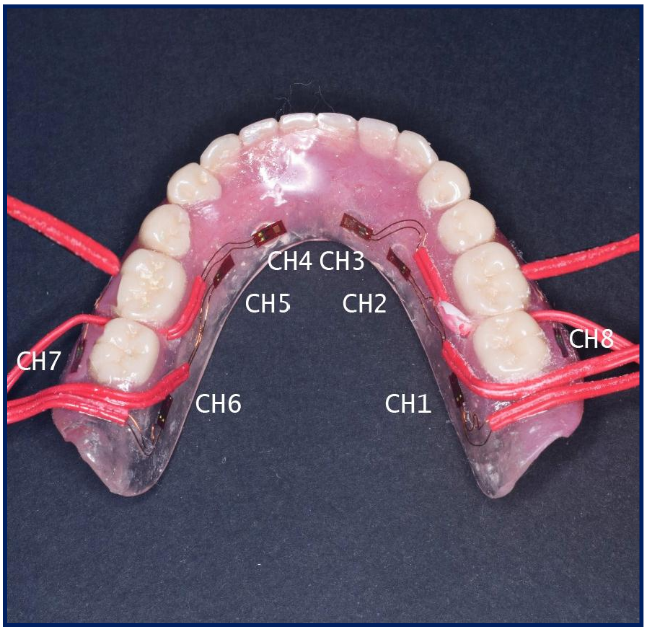
II. Resilient Telescopic Attachments Construction

After three months, implants were uncovered, and healing abutments of appropriate gingival height were connected to the implants. Custom tray was constructed for mandibular ridge with opening over implant sites and border molded with green compound. Long transfer copings were connected to the implants and open tray impression was made. The transfer copings were splinted with Duralay resin to avoid movement during impression making. Implant analogues were connected to the implants and the impression was poured.

Designing of the primary coping with special parameters for all patients concerning 6mm height (4mm gingival height was parallel and the occlusal 2mm was occlusaly tapered 6-7°).13 The computer numeric control (CNC) data were transmitted to the milling machine and connected to CAD system (imes-icore 350i pro) to mill the primary crowns from Titanium (CORITEC Titan Grade 5). The primary copings were tried intraorally. Scanning of each primary coping separately on the cast and designing secondary copings with minimal wall thickness of 0.5 mm and an occlusal space (0.3mm) was built in between the primary and secondary copings.13 Mechanical projections were added to the design of each secondary crowns, to help in mechanical interlocking of the secondary copings to the denture base material.24 After milling the secondary copings from Titanium (CORITEC Titan Grade 5), trying in of the 1ry and 2ry copings intraorally then direct Pick-up of secondary copings to the lower denture

III.Measurement the denture base deformation

Denture strains were measured 3 months after using the prostheses to enhance muscle adaptation. The deformation of the denture base was measured by calculation of the strain within the denture base as described by Elsyad et al..1,25,26 Eight strain-gauges (KFG-1-120-C1-11L1M2R; KYOWA, Tokyo, Japan; resistance 119.6±0.4% **Ω**; gauge factor: 2.08±1.0%) were adhered to the polished surface of each denture using a special adhesive. The gauges were aligned horizontally parallel opposite to each attachment 1 and on lingual and buccal polished surface related to molar area2 as following: (Ch1 lingual right 2nd molar, Ch2 first right abutment, Ch3 second right abutment, Ch4 third left abutment, Ch5 fourth left abutment, Ch 6 lingual left 2nd molar, Ch7 buccal left 2nd molar, Ch 8 buccal right 2nd molar). (Figure 2)



The fine lead wires were brought through the interproximal acrylic resin between artificial teeth and distal to 2nd molar. The wires were adhered to the labial polished surface with a special resin to avoid accidental movement during biting and emerged from patient mouth at midline. The gauges were isolated from saliva with a Chloroprene rubber (HAMATITE-Y., KYOWA). To decrease the effect of temperature of the oral cavity, each active gauge was connected to a dummy gauge (cemented on an acrylic plate) in a half Wheatstone bridge. The resulted eight half-bridge circuits were connected to terminals of the multichannel strain-meter (Tinsely precision instruments, Model 8692, RH1 3LG, Surrey, UK). Strain registrations were performed during maximal voluntary clenching without food. Data capture software was used to record the output data from the strain gauges as microvolts (μV). The highest positive or negative μV values were selected from each channel, and the mean μV of the five tests was calculated. This was converted into microstrain (με) using the appropriate gauge factor equation: Strain (Ɛ) = 4 Vout/Vin GF, where Vout is the excitation voltage (output) provided by the manufacturer (0.577V) and Vin is the measured voltage (input), and GF is the gauge factor provided by the manufacturer (GF = 2.0).

Statistical analysis

Shapiro-Wilk test was used to identify the normal distribution of data. The marginal adaptation data was parametric (met the normal distribution) and presented as mean±SD. Two-way ANOVA was used to compare denture strains between group, and channels for each clenching conditions. If significant differences were detected, Bonferroni pairwise test for multiple comparisons was used. Repeated ANOVA was used to compare clenching conditions for each group followed by Bonferroni pairwise test for multiple comparisons. Statistical analyses were performed with SPSS V. 25 (SPSS, Chicago, IL, USA). P value <0.05 was considered to be statistically significant.

Results:

1. Denture base microstrains (πs) during maximum clenching without food

- Comparison of microstrains between groups and channels during clenching without food is presented in (Table 1).

a) Nature of the strain

- The positive strains denote tension, while negative strains represent compression.

- For curved group, microstrains are negative at ch1, ch3, ch4, ch6, ch7, and ch8. Microstrains are positive at ch2, and ch5.

- For linear group, microstrains are negative at ch1, ch6, ch7, and ch8. Microstrains are positive at ch2, ch3, ch4, and ch5.

b) Comparison of microstrains between groups

- Comparison of microstrains between groups is presented in (Table 1).

- For all channels, linear group recorded significant higher microstrains than curved group.

c) Comparison of microstrains between channels

- Comparison of microstrains between channels is presented in (Table 1).

- For both groups there was a significant difference in microstrains between channels

- For curved group, the order of the highest to the lowest microstrain Ch7>ch2, ch1>ch6>ch8>ch4>ch5>ch3.

- Multiple comparison between each two channels is presented in the same table.

- There was a significant difference between each two channels except between ch6 and ch8.

- For linear group, the order of the highest to the lowest microstrain Ch5>ch6, ch1>ch8>ch7>ch2>ch3>ch4.

- Multiple comparison between each two channels is presented in the same table.

- There was a significant difference between each two channels except between ch7, ch8, ch1, ch6.

Table (1): Comparison of microstrains between groups and channels during clenching without food

	Curved		**Linear**		**2-Way ANOVA**
	X	**SD**	**X**	**SD**	**P value**
Ch1 (right 7 L)	-362.48a	29.41	-772.64a	30.87	<.001*
Ch2 (right 5)	386.10b	15.05	547.44b	44.41	<.001*
Ch3 (right 3)	-123.02c	11.80	401.24c	33.44	<.001*
Ch4 (left 3)	-276.36d	23.57	329.74d	22.02	<.001*
Ch5 (left 5)	149.01e	43.72	857.11e	32.10	<.001*
Ch6 (left 7 L)	-329.81f	2.41	-780.21a	29.48	<.001*
Ch7 (left 7 B)	-396.56g	15.02	-672.17f	6.85	<.001*
Ch8 (right 7 B)	-317.74f	43.91	-685.91f	15.08	
2-Way ANOVA P value	<.001*		<.001*		

X; mean, SD; standard deviation, *p is significant at 5%. Different letters in the same column indicate significant difference between each 2 channels (Bonferroni test<.05), while same letters indicate no significant difference (Bonferroni test>.05)

Discussion:

Fracture failure is a problem associated with complete denture prostheses. This issue can be developed in implant-retained overdentures, especially in the mandible. The implant number may have some influence on this mechanical complication.[27] However, the relationship between the implant number and mandibular overdenture fracture has not been properly addressed.[19] Denture strains were evaluated in several invitro studies; the experimental setup for these studies will not replicate the clinical circumstances in the oral cavity such as the presence of saliva, the thickness and compressibility of the soft tissues. Also, the application of force is usually performed using universal testing machine at a constant load which are differ from the power and direction of occlusal force of the masticatory muscles of the patient.[28] Thus the most precise evaluation denture strains and deformation of overdentures, should be made clinically in patient mouth (in vivo).[29]

Implant location plays an important role in implant success. The success rate of implants in the anterior regions seems to be higher than in the posterior regions of the jaws, mostly due to the quality of bone: about 12% difference between anterior maxilla and posterior maxilla, and about 4% difference between anterior mandible and posterior mandible.[30]

Comparison between two groups during maximum clenching without food revealed that linear configuration group had the highest denture base microstrains than curved configuration group. In curved configuration the denture saddles -because of mucosal resiliency-act as a cantilever when occlusal load was applied creating a situation like class I lever in mechanics. Where the distal most implants (implants at second premolar position) acts as a fulcrum.[31]

Such implants counteract the free overdenture rotation during posterior loading and increase the chance of implant overloading. Linear configuration may enhance overdenture rotation, with twist-free load transmission to the implants due to decreased A-P spread (distance from line pass through most distal implants perpendicular to the most anterior implant at midline).[31] So that, During clenching without food denture base opposite to implants sites recorded tensile strain for linear group (ch2, ch3, ch4,ch5) and only opposite to the most distal implants in curved group (ch2 and ch5). This may be attributed to the compressibility of the oral mucosa during maximum voluntary clenching may cause telescopic primary crowns to act as a fulcrum which may increase tensile strain at level of the top of telescopic crowns.[25] The four abutments in linear group within a fulcrum line and all of them loaded together but in the curved group the fulcrum line passes only through the most distal one. The tensile strains tended to induce crack formation that may propagate to denture fracture. The increased tensile strains are in line with previous in vitro[25,32,33] and in vivo[1] studies in which the authors reported increased tensile strain close to the top of overdenture abutments. This could be attributed to the larger dimensions of the telescopic crowns occupied in the denture base that may cause a decrease in the thickness of the acrylic resin at this area. Also, the inter-implant distance in linear configuration decreased comparable to the curved configuration which decrease the thickness of the acrylic resin between abutments and the curved configuration follows arch anatomy and more suitable with four implants assisted overdenture, all may explain why microstains increased in linear group than curved one.

Denture base opposite to the posterior (most distal) implants, showed the highest strains. These may be due to these implants act as a fulcrum when the overdenture was loaded posteriorly and received intrusive forces. A similar finding was reported in invitro study conducted on 4 implant supported overdenture with telescopic attachment.[34]

The limitations of this study include the small sample size, the short evaluation period, and the lack of control group. Future studies are needed to evaluate the longevity of the denture base, prosthetic aspects and complications of both four-implant configurations on denture base deformation.

Conclusion:

Within the limits of this short-term crossover study, the following conclusions could be drawn:

- Curved configuration is recommended to be used for mandibular four-implant overdentures as they were associated with reduced denture base deformation compared to Linear configuration

- Future long-term studies are needed to evaluate the prosthetic aspects (especially reinforcement of the denture base) and maintenance of implant overdenture attachment system.

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