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STRAINS INDUCED IN CAD/CAM MILLED MANDIBULAR IMPLANT RETAINED OVERDENTURES IN VIVO STRAIN GAUGE ANALYSIS

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ABSTRACT

Purpose: The introduction of computer-aided design/computer-aided manufacturing (CAD/CAM) technology to the field of removable prosthodontics has recently made it possible to fabricate complete dentures using prepolymerized polymethyl methacrylate (PMMA) blocks that are claimed to have better mechanical properties. However, little was published concerning the clinical deformation of CAD/CAM PMMA. The purpose of this study was thus to compare the clinical deformation of CAD/CAM processed PMMA and conventionally processed heat-cured PMMA implant retained mandibular overdenture bases.

Materials and Methods: Thoroughly selected ten completely edentulous patients have received two dental implants in the lower canine region. Two duplicate mandibular overdentures were constructed using CAD/CAM milled PMMA and conventionally constructed heat-cured PMMA. Self cure acrylic resin was used to pick up the attachments to the fitting surface of the mandibular overdenture base. Six linear strain gauges were attached to the lingual side of the polished surface of both overdenture bases to measure strains induced during maximal clenching and gum chewing.

Results: Higher strain values were recorded with the conventionally constructed heat-cured PMMA overdentures compared to CAD/CAM constructed PMMA overdentures. The recorded strains were mainly compressive at the midline while the strains at implant sites were tensile. Higher strains were recorded during clenching compared to gum chewing in both assessed overdentures.

Conclusion: CAD/CAM constructed PMMA implant-retained mandibular overdenture exhibits less denture deformation during function compared to conventionally constructed heat-cured PMMA overdenture.

Key words: CAD/CAM dentures, PMMA resin, strain, deformation, denture base, implant, overdenture.

INTRODUCTION

Dental implants supported and or retained prostheses are successful treatment options to replace missing teeth. Their survival and success rate is over 90% on the long term.[1] Implants are recognized to improve the retention and stability of overlying dentures and the masticatory efficiency, comfort and the overall satisfaction of partially and or completely

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edentulous patients.[2] Implant retained overdenture (IOD) is accepted to be an effective treatment option used to get over the functional inefficiencies accompanying with conventional dentures.[3,4]

According to the McGill consensus on overdenture[5], the installation of two conventional implants is considered the standard requirement to support and or retain mandibular overdentures which are nowadays the first treatment option for an edentulous patient.[6]

In spite of the many benefits of IOD, mechanical and biological complications were reported. These include denture base deformation and fracture, attachment wear, bone loss, peri-implant mucositis, peri-implantitis and implant fracture.[7] Denture base deformation is reported to cause soreness in the underlying mucosa, ulcer formation and residual alveolar ridge resorption.[8]

Denture base fracture especially over implant abutments is a longstanding frequent clinical problem in prosthodontics. Fracture has a tendency to exist in this area due to concentration of stresses and insufficient thickness of acrylic base around the attachments.[9,10] Denture fracture is a consequence of crack origination and propagation in areas having high stress concentration.[11] It thus seems important to demonstrate strains distribution in overdentures in an attempt to minimize the risk of fracture.

Studies on mechanical properties of overdenture bases revealed high level of strain on the overdenture base adjacent to the top of implant abutments.[12,13] Stress transmission and distribution resulting from occlusal forces differ considerably in IODs and conventional complete dentures.[14] This is attributed to the comparably thin overdenture bases due to the space occupied by abutments. Moreover, under functional forces, abutments act as a fulcrum of rotating movement causing concentration of great stresses in the attachment housing area.[15,16] Excessive load may thus lead to denture base fracture. Moreover, implant fracture, periimplant bone loss and consequent implant failure may occur.[17,18]

Many years ago, polymethyl methacrylate (PMMA) was used as the most common denture base material.[19] However, the resins are liable to fracture as the material is brittle on impact.[20]

After a long period of traditional construction of removable prostheses,[21] computer aided-design/ computer aided-manufacturing (CAD/CAM) technology have been newly introduced in dental work to fabricate complete denture, immediate denture and implant retained and or supported overdenture[22,23]. CAD/CAM fabricated dentures have been reported to better satisfy elderly and debilitated patients.[21,24]

The CAD/CAM dentures are fabricated in two clinical appointments[21] using prepolymerized PMMA (CAD/CAM PMMA) supplied in the form of discs condensed under elevated pressure and heat. These discs are milled to shape dentures.[23,25] The milled CAD/CAM fabricated dentures exhibit improved mechanical properties and greater density compared to conventional PMMA dentures.[26,27] However, reports concerning the deformation properties of CAD/CAM PMMA fabricated two-implant-retained mandibular overdentures are lacking in the dental literature. This study thus aimed to assess the strain that causes deformation of CAD/CAM PMMA fabricated two-implant-retained mandibular overdentures compared to conventionally fabricated PMMA overdentures.

CAD-CAM fabricated removable prostheses were reported to exhibit less residual monomer content, improved physical properties, reduction in polymerization shrinkage and increased denture base adaptation. Also, CAD-CAM fabricated removable prostheses require fewer patient visits and easier remakes. [28,29]

Although deformation of conventional mandibular denture bases was investigated in numerous in vivo and invitro studies [30,31] studies; the deformation of tooth-retained mandibular overdentures has been documented,[13,16] the clinical deformation of implant-retained mandibular overdentures constructed using three different impression techniques was also investigated[32] . However, the deformation of different implant-retained mandibular overdenture fabricated techniques has not been examined. Therefore, the goal of the current study was to assess and compare the deformation of CAD-CAM processed PMMA implant-retained mandibular overdentures bases to the conventionally processed heat-cured PMMA bases.

MATERIALS AND METHODS

Patients' criteria

Ten completely edentulous male patients whose ages ranged between 50 to 60 years, with a mean age of 56 years complaining from insufficient retention and stability of their lower dentures were selected from the out-patient clinic of the Prosthodontics Department, Faculty of Dentistry, Mansoura University. The selected patients had healthy mucosa firmly attached to the residual alveolar ridges, class I maxillo-mandibular jaw relationship and adequate interarch distance. The patients exhibited mandibular bone width and height in the canine regions sufficient to receive two implants 14 mm in length and 3.6 mm width as verified by pre-operative cone beam computed tomography (CBCT).

Heavy smokers, patients having TMJ problems, diabetes, osteoporosis or immune deficiency were excluded. Also, patients on radiotherapy to the head and neck or on anticoagulant therapy were excluded.

All participants signed a written consent after they have been thoroughly informed about the full details of the study. The treatment protocol of this study was approved by the ethical committee of the Faculty of Dentistry, Mansoura University.

Surgical and prosthetic procedures

Prior to implants placement, new conventional complete dentures were fabricated for all patients. Radiographic stents were also fabricated.

The surgical procedures for implant installation were carried out under local anesthesia. Each participant received two dental implants 14 mm in length and 3.6 mm in width (Dentium, Corea), in the canine region bilaterally. Stereo-lithographic surgical guide stent was used to mark the implant position. Tissue punch was used to cut through the soft tissues down to the crest of the ridge to locate the exact position for drilling. Successive color coded implant drills were used to prepare implant site osteotomies gradually until the prescribed implant diameter was attained. The implant was inserted manually into the prepared implant site by hand ratchet. The denture base was relieved above the area of implants and tissue conditioning material was applied. All patients were instructed to use postsurgical medications and to follow oral and denture hygiene care.

Three months later, implants were uncovered and healing abutments 3mm in height were screwed and maintained for two weeks. The denture was relieved over the healing abutments and relined with soft lining material. Two weeks later, the soft liner was removed and the attachment abutments (Dentium, Corea) were connected to the implants **(Figure 1)**. The processing caps and metal housings were inserted on the implants. Secondary impression was recorded using elastomeric impression material (Silaxil Light Body - LASCOD Italy). The processing caps and metal housings were removed from the impression and the impression was poured with extra hard stone (Kimberlit extra-hard high density die stone-Girona-Spain).

Maxillo-mandibular jaw relation was recorded and semi-anatomical acrylic teeth (Ruthinium acrylic teeth, Acry Rock Company, Italy) were set up.

According to the lower denture base materials and processing techniques, the constructed overdentures in this study were classified into two equal groups. **Group I:** included prepolymerized PMMA resin milled lower overdenture bases. **Group II:** included conventional heat cured acrylic resin lower overdenture bases.

Fig. (1) Attachment abutments connected to the implants.

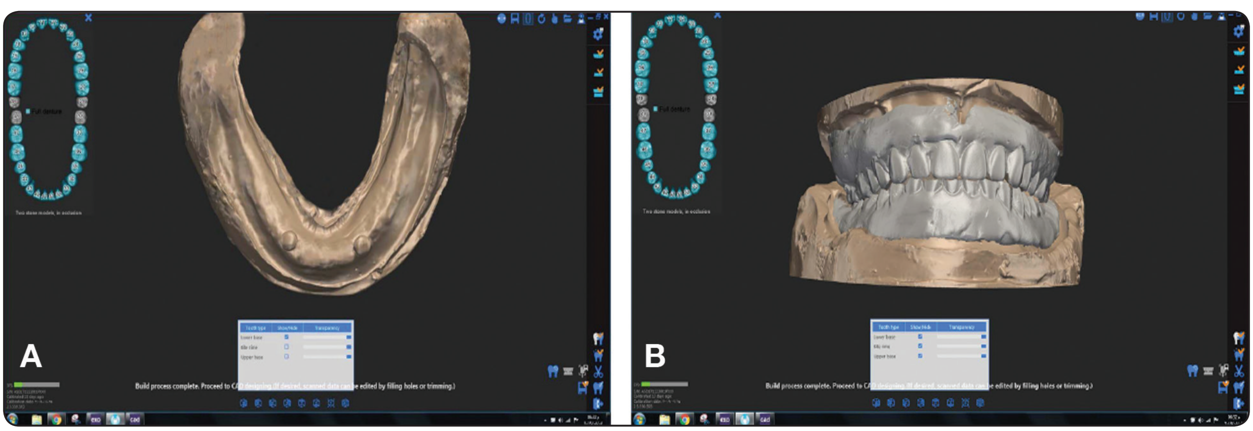
In Group I, mandibular overdenture were designed using CAD software and were fabricated by milling the denture bases using prepolymerized PMMA discs as follows: The lower master cast and the lower trial denture were scanned using 3D scanner (DOF Swing dental scanner, Corea) **(Figure 2 A&B)** to obtain the standard tessellation language (STL) file format. STL file format was imported into the CAD software (EXO CAD. Dental DB 2.2Valleta) to begin the design process and make a rapid prototype of the trial denture. While creating STL file of the designed denture base, the CAD software automatically created sockets for teeth in the denture base **(Figure 3 A,B,C and D).** STL file of the designed denture base was then imported into the milling machine (MILL Box 2018 milling machine: ARUM, 400 Corea) to mill the prepolymerized PMMA discs (PMMA Disc, bio HPP, Germany) and fabricate the denture base **(Figure 4 A&B).** The denture teeth were milled, finished and bonded into the milled base with a bonding agent (Visio Lign: Bredent). The CAD /CAM PMMA denture was then finished.

In Group II, mandibular overdenture bases were fabricated from heat cure polymethyl methacrylate resin (Major Prodotti Dentari S.p.A; Italy) following the conventional processing technique.[33] Waxed up dentures were flasked and in accordance with the manufacturer's directions, the acrylic resin polymer and monomer were mixed (powder/liquid ratio of 2.1 g/1 mL). Conventional packing and polymerizing processes were carried out using the long curing program (8 hours at 74 degrees C). The processed dentures were laboratory remounted, finished and polished.

At insertion appointment, proper denture base fit, border extension and premature occlusal contacts were checked.

Attachment connection

A piece of rubber dam was placed over the attachment abutments (Dentium, Corea) to block out undercuts and create space around the abutments. The female housings were repositioned over the attachments. Dentures were inserted and tested



Fig,(2) Scanned lower master cast (A) and lower trial denture (B).

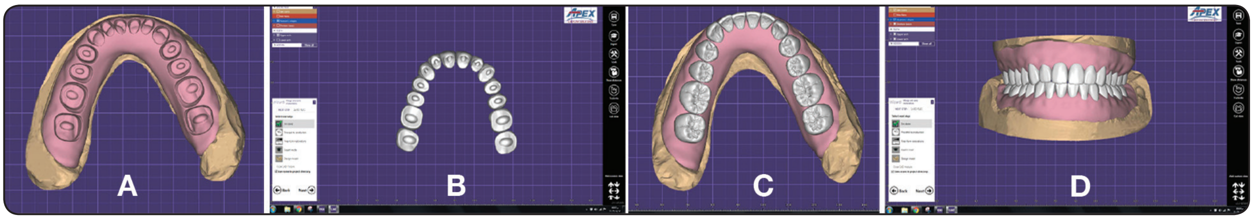


Fig.(3) A, Virtual mandibular overdenture on the master cast with teeth sockets. B, Virtual teeth. C, Virtual mandibular overdenture on the master cast with arranged teeth. D, Virtual maxillary and mandibular dentures on the master casts.

for presence of interference with the attachments, then readjusted for maximum planned occlusal contacts in centric and eccentric relations. Self cure acrylic resin was used to pick up the attachment to the fitting surface of the mandibular overdenture bases **(Figure 5 A&B)**. Occlusal refinement was carried out to ensure even occlusal contact. After one month, the patient was recalled to assess the strains induced in the implant assisted mandibular overdenture bases.

Measurements of strains induced to implant assisted OD

Strains induced to the IOD bases were carried out in the Faculty of Engineering Mansoura University using a multichannel strainmeter.

Strain gauge fixation

Six linear 1mm length strain-gauges (KFG-1-120-C1-11 L1M2R, KYOWA electronic instruments CO., Ltd., Tokyo, Japan) with resistance 120.4± 0.4Ω, gauge factor 2.13±1.0%, adaptable thermal expansion =11.7 PPM/°C and temperature coefficient of gauge factor+0.008%/°C) were attached to the lingual side of the polished surface of mandibular overdenture using applicable gauge cement (KYOWA CC-33A, EP-34B, Japan) in the following positions: At the midline (Ch3 and Ch4), opposite to implant abutments (Ch1 and Ch2) on the right side and opposite to implant abutments (Ch5 and Ch6) on the left side. The long axes of all strain gauges were parallel to the incisal edges of the lower anterior teeth and oriented in mesio-distal

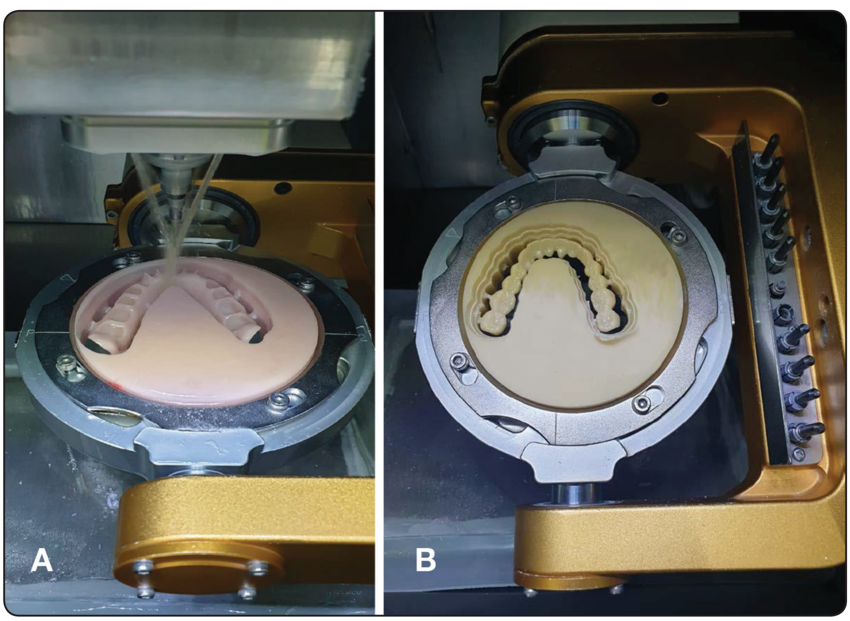


Fig.(4) A, prepolymerized PMMA disc in the milling machine to fabricate the denture base. B, prepolymerized PMMA disc in the milling machine to fabricate the denture teeth.

Fig. (5) Mandibular overdentures fitting surface with picked up attachments A. CAD/CAM milled PMMA B. Conventional PMMA.

direction. The upper gauges (Ch1, Ch3, and Ch5) were positioned at the level of middle portion of the abutment and the lower gauges (Ch2, Ch4, and Ch6) were positioned 5 mm below the upper gauges **(Figure 6)**. The fine lead wires of strain gauges were completely isolated from the moisture of the oral environment by a thin layer of Chloroprene rubber coating material (HAMATITE-Y., KYOWA electronic instruments CO., Ltd.) to avoid short cuts. The gauge wires were assembled together as a bundle and protruded from the mouth to be linked to the ends of the multichannel strainmeter (HAMATITE-Y., KYOWA electronic instruments CO., Ltd) **(Figure 7)**.

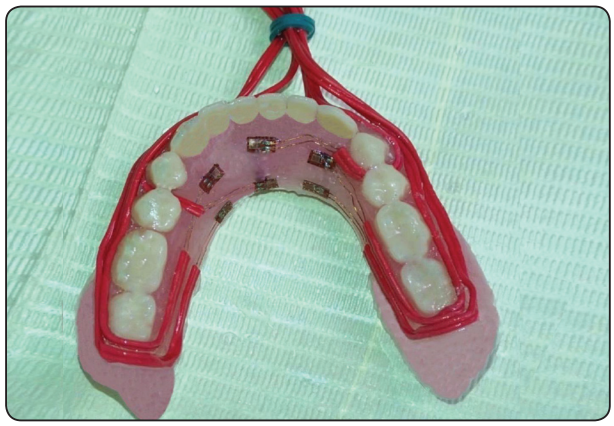


Fig. (6) Strain gauge locations

Strain measurements

Strain recordings were carried out at maximum voluntary clenching and gum chewing. The patient was requested to achieve a set of ten times of maximum biting; each bite continued about two seconds and separated by five seconds as a relaxation period. The patient was then instructed to perform movements simulating chewing movements for about one minute. Another set of maximum bites and chewing were performed and recorded in the same manner. Finally, the patient was instructed to clench in maximum intercuspal position.

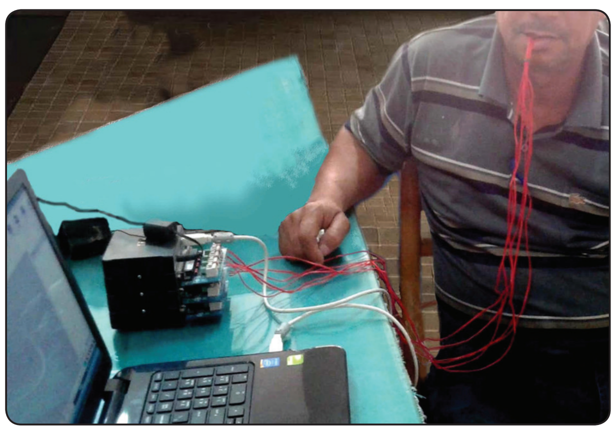


Fig. (7) Gauge wires linking to the ends of the multichannel Strainmeter

Data capture software Kyowa DCS_100A (Dynamic data acquisition software) was used to record the output data from the strain gauges as microvolts (µV) over time. This was converted into microstrain (µV) using the appropriate gauge factor equation:

$$\text{Strain } (\varepsilon) \backsimeq \frac{4\ V_{out}}{V_{in}\ GF}$$

Where: V_{out} is the excitation voltage (output) ($V_{out} = 0.577V$).

V_{in} is the measured voltage (input).

GF is the gauge factor (*GF* = 2.13).

A longer relaxation period was allowed. A set of consecutive gum chewing cycles that lasted for ten seconds were performed on the right side (working) followed by 10 minutes relaxation period.[34,35]

Each set of both clenching and gum chewing was repeated five times and the mean values were collected and statistically analyzed.

The strain measurement procedures of implant assisted mandibular overdenture bases were recorded for both heat cured denture bases and CAD-CAM bases respectively in three repeated sittings separated by one day rest to avoid patient fatigue and mucosal soreness. The mean value of three trials was considered as a valid mean.

Statistical analysis

Normality of the recorded strain values were verified using Shapiro-Wilk test. Statistical analyses of data were accomplished using SPSS software package version 20.0. (SPSS, Inc., Chicago, IL USA). Paired *t*-test was applied to compare microstrains between conventional heat cured PMMA group and CAD/CAM PMMA group during maximal clenching and gum chewing. As regards between-channel comparisons, one-way ANOVA test was applied, followed by Bonferroni correction for post hoc analysis. P-value of less than 0.05 was considered statistically significant.

RESULTS

The descriptive analysis of the recorded microstrain values of the six strain gauges located at midline (Ch3 and Ch4), right area (Ch1& Ch2) and left area (Ch5 & Ch6) of both conventional heat cured PMMA and the CAD/CAM PMMA processed dentures during clenching and gum chewing are shown in tables (1 and 2). The registered strain values at Ch3 and Ch4 were negative indicating a compressive strain while at Ch1, Ch2, Ch5, and Ch6 were positive indicating a tensile strain.

The results of this study revealed higher strain values in the conventional PMMA dentures during clenching and gum chewing compared to the CAD/CAM processed dentures. The difference was highly significant (p=0.000). This is evident in tables (1 and 2).

The results also revealed that clenching indicated higher means of microstrain in both conventional PMMA dentures and CAD/CAM PMMA dentures at all channels when compared to gum chewing. The difference was statistically significant ($P < 0.05$) at all channels when compared with gum chewing. This is evident in figures (5 and 6).

A significant difference in the mean values of micro strains was found between different channels (one-way ANOVA, $p<0.05$) (Tables 1 and 2). The highest mean of micro strain values were recorded in the conventional PMMA dentures during clenching at Ch1, while the lowest mean of micro strains were recorded at Ch6 in the CAD/CAM PMMA processed dentures during gum chewing.

Between-channel comparisons revealed a significant difference ($P<0.05$) for all channels except between Ch1 and Ch5 & Ch2 and Ch6 during clenching for both types of dentures and during gum chewing for CAD/CAM processed dentures as evident in table (3).

TABLE (1): Descriptive analysis of microstrain values and P values of conventional PMMA and CAD/CAM PMMA implant overdenture bases at different measuring channels during clenching.

Group / Channel	Conventional PMMA			CAD/CAM PMMA			P value
	X ± SD	median	min:max	X ± SD	median	min:max	
Ch1	389.1 ± 13.5	307.6	199: 450	125.5 ± 5.2	100.1	84:153	0.000
Ch2	298.3 ± 17.9	159.9	144:350	80.7 ± 2.5	60.6	35.5: 95	0.000
Ch3	-230.2 ± 21.3	-210.6	-292:52.4	-105.4 ± 4.1	-89.5	-130.3:-29.6	0.000
Ch4	-358.9 ± 21.5	-297.4	-466:-151	-113.3 ± 6.5	-92.7	-155.4:-20.3	0.000
Ch5	378.9 ± 17.2	325.5	225:410	120.8 ± 7.5	99.5	79: 159.4	0.000
Ch6	287.9 ± 22.1	176.9	120:-290	75.49 ± 5.3	56.06	39.5:98.3	0.000
F (p value)	5.495 (0.03)			4.992 (0.03)			

X: mean; SD: standard deviation; min: minimum; max: maximum.

TABLE (2): Descriptive analysis of microstrain values and P values of conventional PMMA and CAD/CAM PMMA implant overdenture bases at different measuring channels during gum chewing.

Group / Channel	Conventional PMMA			CAD/CAM PMMA			P value
	X ± SD	median	min:max	X ± SD	median	min:max	
Ch1	169.2 ± 15.3	197.6	99: 250	75.6 ± 2.3	49.1	34:73	0.000
Ch2	120.5 ± 17.8	159.9	54:220	50.9 ± 2.7	28.6	15.5: 55	0.000
Ch3	-145.6 ± 9.2	-160.6	-192:22.4	-62.5 ± 2.8	-29.5	-55.3:-19.6	0.000
Ch4	-158.7 ± 15.7	-197.4	-266:-95	-69.5 ± 3.8	-32.7	-65.4:-20.3	0.000
Ch5	130.8 ± 8.3	115.5	55:135	80.9 ± 4.2	39.5	79: 159.4	0.000
Ch6	90.5 ± 9.3	76.9	50:95	45.94 ± 2.16	16.06	11.5:48.3	0.000
F (p value)	4.573 (0.03)			3.059 (0.05)			

X: mean; SD: standard deviation; min: minimum; max: maximum.

TABLE (3): Pairwise comparison using Bonnferroni post hoc test between different measuring channels for conventional PMMA and CAD/CAM PMMA overdentures during clenching and Gum chewing.

	Clenching		Chewing	
	CAD/ CAM	Conventional	CAD/ CAM	Conventional
Ch1 – Ch2	< 0.000	< 0.000	0.01	0.05
Ch1 – Ch3	0.001	0.01	0.001	0.01
Ch1 – Ch4	0.002	0.05	0.002	0.01
Ch1 – Ch5	0.07	0.204	0.235	0.05
Ch1 – Ch6	< 0.000	< 0.000	< 0.000	< 0.000
Ch2 – Ch3	< 0.000	< 0.000	0.001	0.001
Ch2 – Ch4	< 0.000	< 0.000	0.001	0.002
Ch2 - Ch5	< 0.000	< 0.000	0.001	0.002
Ch2 – Ch6	0.09	0.079	0.191	0.05
Ch3 - Ch4	0.001	0.01	0.001	0.001
Ch3 – Ch5	0.001	0.02	0.002	0.001
Ch3 – Ch6	< 0.000	< 0.000	< 0.000	< 0.000
Ch4 – Ch5	0.02	0.05	0.001	0.01
Ch4 – Ch6	< 0.000	< 0.000	< 0.000	< 0.000
Ch5 – Ch6	< 0.000	< 0.000	< 0.000	< 0.000

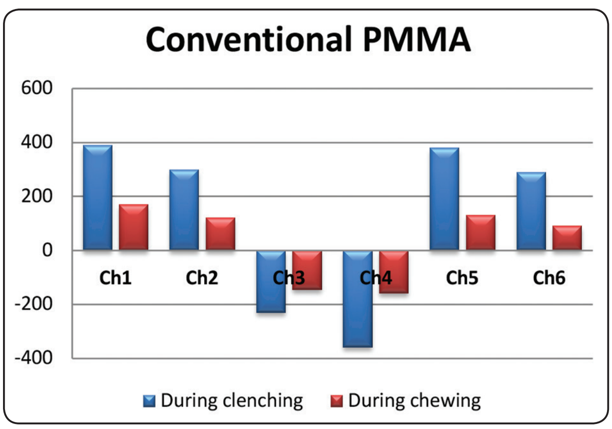


Fig. (8): Comparison of microstrain values of conventional PMMA implant overdenture bases at different measuring channels between clenching and gum chewing.

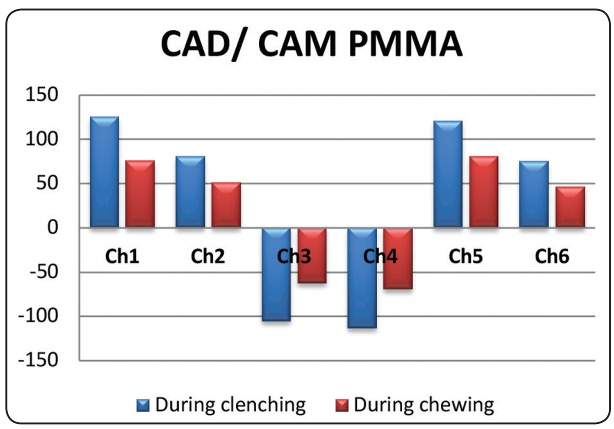


Fig. (9): Comparison of microstrain values of CAD/CAM PMMA implant overdenture bases at different measuring channels between clenching and gum chewing.

DISCUSSION

Force distribution is expected to be different in implant assisted prostheses (IOD) compared to conventional complete denture.(14) Longitudinal clinical reports have shown that, in IODs microstrains are concentrated around attachment components present in the fitting surface of IODs.(8,16) leading to an 80% risk of denture base fracture, and a 38% of opposing conventional maxillary denture fracture.(36,37)

The introduction of new denture manufacturing techniques and materials seemed necessary to enhance the properties of complete dentures. (38) The recently introduced computer-aided design and computer-aided manufacture of (CAD/CAM) removable denture(39,40) absolutely reports this request, as it has essentially enhanced denture manufacturing procedure. Instead of the manual mixing of powder and liquid and process the mix to an arbitrary manual curing procedure, the resin blocks of poly(methyl methacrylate) (PMMA) used for construction of CAD/CAM denture bases are precisely made-up industrially(25,26) and cured under great heat and pressure.(26,27, 41) Consequently, it has been supposed that the CAD/CAM resins are more condensed and have less micro-porosities(41) consequently, the produced dentures have superior mechanical properties.(42) This is advantages in manufacturing dentures with thinner bases. (43)

Companies have supposed that CAD/CAM dentures have improved mechanical properties compared to conventionally fabricated heat cured dentures.(21,23,26) However, information about the microstrain induced within dentures fabricated by this technique and the resulting deformation especially when these dentures are overlying implants are lacking in the dental literature, the present study was thus carried out to clinically assess the microstrains and hence denture base deformation.

The use of strain-gauge in both in vitro and in vivo strain assessment is documented.(12,32,44,45) Owing to the small size and linearity of the resistance rate change, strain gauge analysis is one of the best possible tools for assessing microscopic deformation with minimal intervention during testing.(34) Additionally, strain gauges give quantitative strain assessments.(11) Nonetheless, strain gauges assess only the surface strain. Thus, estimating internal stresses within dentures should better be backed up by photoelastic or finite element analysis.(31)

In this study, patients and prosthetic appliances were standardized by comparing the patients with themselves after using two identical overdentures to allow the same denture base thickness, also, to ensure the same size and location of artificial teeth, which may thus have large impact on the magnitude and direction of force transmitted to the denture, the induced stresses and hence the degree of denture deformation. (31) Moreover, since the thickness of the soft tissue differs among people, and even in the same person in different regions. Such differences in soft tissue thickness may increase or decrease the stress around the implant. As it was previously reported that the denture base deformation is affected by the underlying soft tissue. (46)

The improved strain resistance of the CAD/CAM dentures could be due to the unique manufacturing technique and the high temperature and pressure used in polymerization of CAD/CAM PMMA pucks.(26) This finding is also approved by the results of a previous study reporting that polymerization of PMMA at high temperature and pressure enhances the mechanical properties of conventional PMMA.(41) This could be explained by the previously reported fact that the increase in temperature and pressure increases the molecular weight average of the PMMA polymer in addition to that, the decreased concentration of residual monomer and in turn in the internal voids.(27, 41,47)

The previously proved decrease in residual monomer content of CAD/CAM processed dentures causes decrease in water sorption that enhance flexural properties of CAD/CAM PMMA which in turn affects its resistance to the induced microstrains.[20,41] The additives in CAD/CAM PMMA could also be another cause for the improved strain resistance of CAD/CAM dentures since they enhance the elastic moduli of PMMA.[48]

The low strain resistance of conventionally processed PMMA dentures might thus be attributed to the presence of internal porosities and voids accompanied with the manufacturing procedure of the conventional heat cured PMMA as previously described and proved.[49] Also, the presence of residual monomer could explain the increased risk of denture base deformation.[49]

The insignificant difference in microstrain recorded at chewing and non-chewing sides (Ch1and Ch5, Ch2 and Ch6) during gum chewing with CAD/CAM dentures may be related to the previously reported enhanced flexural strength, flexural modulus, and impact strength in comparison to the conventional heat-cured fabricated denture.[50] These properties probably caused better stress distribution on both right and left sides rather than being concentrated at the functioning side. This is probably advantageous in reducing ridge resorption and transmitting less stresses on the underlying implants when IODs are used.[51]

The significant difference noted between chewing and non chewing sides when conventional PMMA fabricated denture are used may be attributed to stress concentration of the chewing forces on the chewing side causing more induced strains to the denture base, hence causing more base deformation.[52] Clinically on the long term, the prosthesis and implant and their components could be negatively affected by concentration of these increased occlusal loads, which may thus end in mechanical failure.[53]

The recoded strains at the level of the attachment metal housings on both the right and left sides were tensile in nature in both CAD/CAM dentures and conventionally processed dentures. This is in agreement with other studies where great tensile strains were found both in vitro and in vivo in implant assisted conventionally fabricated PMMA overdenture bases on top of ball abutments during clenching.[12,32] The increase in tensile strains at and above the attachment metal housings allow cracks initiation at these areas resulting in denture base fracture. On the other hand, compressive strains that were assessed at the midline of both types of assessed overdentures were considered comparatively better compared to tensile strain as this may cause less incidence of denture base fracture.[54] This is explained by the fact that polymethyl methacrylate resin, exhibits better strength when subjected to compression than in tension.[55] Thus, areas of an acrylic resin bases subjected to tensile stresses are more susceptible to failure than the areas subjected to compressive stresses.[31]

The highest value of strain evident at Ch1 (opposite to middle portion of the abutment at the right side) and the lowest value of strain verified at Ch6 (5 mm below the abutment at the lift side) are in accordance with earlier clinical studies where overdenture fractures were reported to occur in the area around implant abutments.[9, 56, 57] Thus, it seems evident that reinforcement of these parts of the denture base is essential to attain strength of overdenture bases once conventional PMMA denture bases are to be used.

CONCLUSION

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

1. Comparatively less microstrains are induced within CAD/CAM PMMA fabricated implant-retained mandibular overdenture during function compared to conventional heat-cured PMMA fabricated overdentures.
2. More microstrains are induced at the loading side at the level of the metal housing in conventionally processed denture bases than CAD/CAM PMMA fabricated bases.

3. Chewing induces less strains compared to clenching in both CAD/CAM and conventionally fabricated PMMA overdenture dentures.
4. Strains are concentrated at the level of the attachment metal housing in implant retained overdenture.

RECOMMENDATIONS

CAD/CAM milled PMMA is a promising option to fabricate implant-assisted overdentures with longer life expectancy and less need for denture repair.

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