

Stress Distribution in Complete Dentures ()*

Senih ÇALIKKOCAOĞLU (**)

INTRODUCTION

As most of the dentists agree that the maintenance of the supporting structures in a healthy condition must be a prime requisite when constructing a complete denture. However, in spite of the best clinical efforts, the underlying supporting tissues may undergo degenerative changes. In some cases, the general health as well as the nutritional status of the patient may be the cause of these changes. As a dentist, there is nothing to do except to refer the patient to his medical doctor for consultation. In other cases, these changes are felt to be caused by the unequal distribution of functional forces. Observations have shown that the main requisites to eliminate the unequal functional forces seem to be that the impression should be made according to the principles of mucostatics and the occlusal design of masticatory surfaces should be arranged according to the principles of balanced articulation.

(*) This paper was presented at the X Annual Congress of the Iranian Dental Association held in Tehran between the 18th and 22 nd of September 1972.

(**) Ass. Prof., (Dr. med. dent.) Department of Removable Denture Prosthodontics Faculty of Dentistry University of İstanbul TURKEY

Now to begin with, I would like to define and explain a bit some of the concepts I just mentioned in order to refresh our memories.

Today, most of the profession agree quite readily that soft tissues for a complete denture construction should be registered in an unstrained rest position. This is Mucostatic or Passive technique. The mucostatic technique which is attributed to Page¹ demanded the impression material should record without distortion, every detail of the mucosa so that the denture would fit all minute elevations and depressions. However, this is only true for the basal seat area of the dentures. Because in the last quarter of the century, many attempts have been made to mold the periphery of the denture and seal it dynamically according to the functional physiologic limits of the muscles. (2,3,4,5)

The adherents of the mucostatic principle considered interfacial surface tension as the only important retentive mechanism in complete dentures. Therefore, they did not use conventional flanges, because these did not resist vertical displacement which was the only movement capable in interrupting surface tension. To satisfy the above mentioned requirement, metal base should be used rather than the dimensionally unstable acrylics.

The advantages of a metal base as given by Swenson (6) are 1) Better thermal conductivity as compared to the acrylic resins, 2) Increase in tissue tolerance because of a less irritating surfaces and increase in stimulation from heat and cold, 3) Reduction of bulk across the palate which is an important factor to the patient as it creates more tongue space.

On the other hand, the disadvantages of a metal base may be listed as cost due to intricate technique involved and the maintenance problems such as relining, rebasing and posterior palatal seal adjustments. (7) So, the indication of a metal base should be considered very carefully.

The casting of metal base was first reported in 1820 in tin. (8) Since then, some basic metals for casting have been tried and gradually discarded. Today, cast metal bases are usually constructed of chromium alloys. (6, 8, 9).

Another term to be discussed is balance. The prefix (ba) in balance is a variant of bi which means two. The other part of the word comes down from the Latin (lanx) which means plate. So the

original meaning of balance is having two plates. This describes the well-known balance scale.

There is also a balance crane, a crane in which there is a counterbalancing weight opposing the load. Again here is the idea of two components. However, this term has no value in prosthodontics unless it is combined with another term or phrase such as balanced occlusion or balanced articulation. (10)

The Glossary of Prosthodontic Terms (11) gives four definitions of balanced articulation in which the main idea is as follows :

Balanced articulation is such an arrangement of teeth so that in any occlusal relationship as many teeth as possible are in contact, and when changing from one relationship to another, they move with a smooth, gliding motion, free from cuspal interference and maintaining even contact in harmony with mandibular movements.

At this moment, we must keep in mind that there is a difference between occlusion and articulation. (12) OCCLUSION is to bring the mandibular teeth up into contact with the maxillary teeth. This is a static position when the jaws are either centrally or eccentrically related. On the other hand, ARTICULATION is the contacting the upper and lower teeth as the mandible moves to and from centric and eccentric relation. This is a dynamic position of the jaws. So it may be correct to speak of occlusion as any one specific and static phase of articulation.

Balanced articulation is thought primarily in the mouth, but it is arranged and may be observed on articulators. This is generally associated with cusp form of posterior teeth. To accept the concept of balanced articulation is to accept the concept that the mandible makes eccentric movements during function.

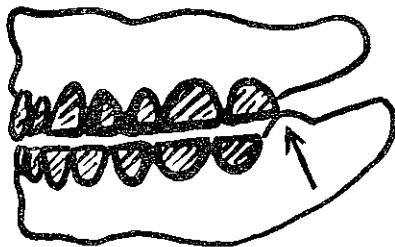


Fig. 1
Courtesy J. J. Sharry

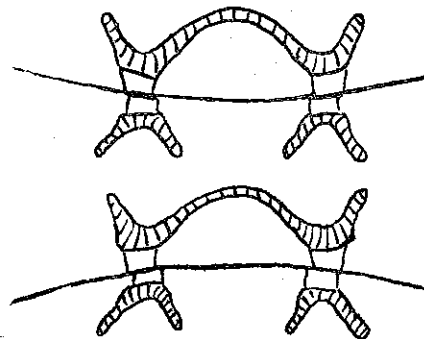


Fig. 2

However, balance in nonanatomic teeth forms can also be accomplished in one of two ways : (13) One can either set the teeth in a compensating curve as is done in anatomic forms, or one can set the teeth in a flat plane and utilize a balancing ramp just distal to the second molar. (Şekil 1) This ramp is adjusted so that the upper second molar will contact it in eccentric movements and 3-point contact will be provided.

One other concept of balanced occlusion is suggested by Pleasure (14) using nonanatomic tooth forms. He sets the bicuspids and first molars in an anti (convex upward) Monson curve, but the second molars in the conventional Monson curve. (Şekil 2) This combination of Monson and anti-Monson curves in posterior occlusion is often referred to as the Pleasure curve. (Şekil 3)

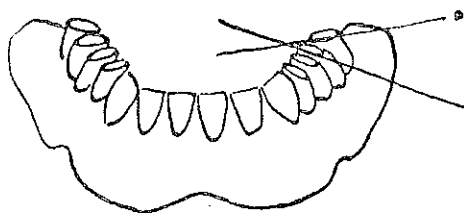


Fig. 3
Courtesy J. J. Sharry

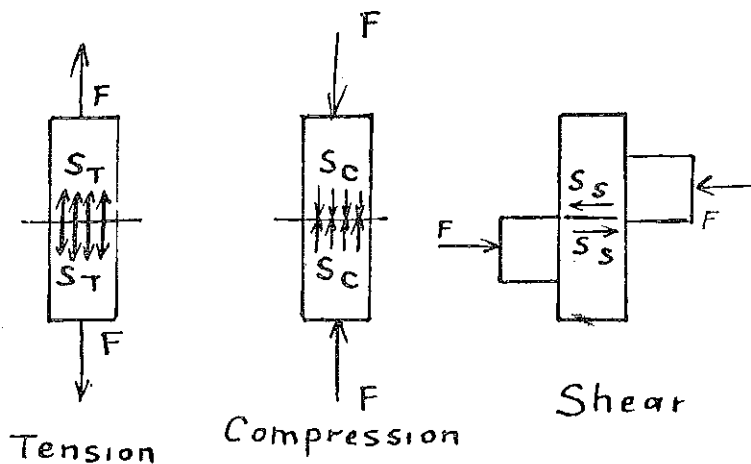


Fig. 4

In any case, research (15) has shown that if the articulation has been balanced it may prevent many shortcomings of the dentures.

Now let's think for a moment that why do we construct a denture?

One of the main reasons of constructing a complete denture for an edentulous patient is of course to enable him to chew his food properly and efficiently. For that, force is required to achieve the chewing act.

As a general concept in physics, FORCE is a kind of action which produces, or tends to produce, or changes the motion of a body.

In reviewing the literature, it was found that many attempts have been made to measure and evaluate the masticatory forces. Early measurements of biting forces were made possible with an instrument called **Gnathodynamometer**. As an example of these investigations, Klatsky (16) has person attempt to chew upon a Gnathodynamometer with a force which they thought they used during mastication of food. He found that the force used was only one-fourth of the maximal force which they could exert on the instrument.

Measurements made more recently with the smaller strain gauge devices have been more precise than those the early equipments. (17,18,19,20) The strain gauge devices are put in the denture base where the sites are predetermined. The gauges are soldered to the lead wires bonded to the base by the epoxy resin. The lead wires are positioned and self curing acrylic resin were flown over them. A carrier preamplifier and recorder are generally used to record all changes that occur in the denture base during the functional tests.

The recent studies made with these devices are more accurate. **However, in general the conclusions are similar.**

«The chewing force causes an internal reaction in the body on which is directed, and that is STRESS. So stress in the internal reaction to the external force and is equal in intensity and opposite in direction to it. Since the applied external force and the internal reaction are distributed over a given area of a body, stress in a structure is designated as the force per unit area. In this respect, stress resembles pressure and both are represented by the same

equation. Stress = $\frac{\text{Force}}{\text{Area}}$

As we all know, stresses can be resolved into the three basic types which are recognized as tension, compression and shear. (Şekil 4)

TENSION results in a body when it is subjected to two sets of forces which are directed away from each other in the same straight line. So the tensile strength is any resistance to deformation of a body by a load which tends to stretch or elongate it.

COMPRESSION results when the body is subjected to two sets of forces in the straight line and directed toward each other. That is the load placed upon a body which tends to compress or shorten it.

SHEAR is the result of two sets of forces being directed toward each other, but not in the same straight line. That is kind of a stress which tends to resist a twisting motion, or a sliding of one portion of a body over another.

In the field of stress analysis, it may be said that the experimental stress analysis has been regarded as a distinct professional branch of engineering, the object of which is the determination and improvement of the mechanical strength of structures. Stress analysis methods have the advantage that they maintain a direct relation with the true physical nature of the problems under consideration.

The principle methods of experimental stress analysis are :

1. Photo elastic - stress analysis
2. Brittle lacquer - coating technique
3. Electronic strain gauges

Photoelastic stress analysis is used in light transmission to study stresses in two or three dimensional models and in reflection in which case a photoelastic coating is cemented to an opaque structure to be studied. The isochromatic fringe patterns in the photoelastic model loaded give the calculation of stresses along two lines of interest as lb/inch² in compression and in tension since different kind of stresses are resulted.

Since the stress distribution is rather complex, one must have two drawing of the models indicating the fringe order in the model and at the surface of the model.

Brittle lacquer coating technique involves spraying the part to be studied with a lacquer in a highly volatile solvent. The solvent is allowed to evaporate under carefully controlled conditions after which the part has been loaded. When tensile strain on the surface of the part exceeds the tensile strength of the lacquer cracks appear. The loads and the position of the cracks are recorded and the strain at the occurrence of the cracks is determined by coating the calibration bar with the lacquer at the time the part is coated.

Electronic strain gauges technique is essentially attaching the gauges just anterior and posterior the part to be studied. Loads are applied statically and in vertical direction. The surface strain at the particular position of the gauges is recorded and calculate accordingly as microincher per inch. This is the change in length occurring per unit length of the body when a stress is applied. The amount of strain will differ with each type of the material subjected to stress as well as with the magnitude of the stress applied. However, the distribution of surface strain is quite complex for a variety of loading positions in an irregular structure such as a dental bridge on which the dynamic or impact stress analysis has also been reported in dental literature (21).

Stress distribution on dental structures are mostly studied in cast partial dentures and fixed prostheses such as inlays, crowns or bridge works. (22-29). In complete dentures, the chewing efficiency with various occlusal patterns and the degree of chewing force are mainly investigated. (30-40) However, there are some stress investigations in dental literature concerning the complete dentures as well.

One of them is in situ investigation which has been undertaken by Koivumaa (41) for the evaluation of a prothyenyl prosthesis. He demonstrated when force is exerted on a flexible object, the distribution of stress is not uniform.

Lambrecht & Kydd (42) have conducted an investigation on complete dentures by means of strain gauges to determine the consistency of the established pattern. This pattern has shown the unequal distribution of force to the underlying supporting tissues.

Regli & Kydd (43) have also undertaken a preliminary study of the lateral deformation of metal base dentures in relation to plastic base dentures and demonstrated that the metal base denture was

quantatively 8.5 times more resistant to lateral deformation than the plastic base denture.

Now, in general practice today, it is felt that the selective grinding after processing the case is not performed unless great discrepancies have been involved, and usually hinge-type articulators are used in the dental laboratories by the technicians. In addition to these, the importance of registering the soft tissues in an unstrained rest position seems not to be fully understood and appreciated. These may be some mistakes done partly by the dentist and partly by the technicians. However, since the proper treatment plan and step by step procedures of the case can be possible only by the dentist who is supposed to know and understand the biologic as well as the mechanical principles involved, the dentist himself must be responsible of failure. In the part of findings, I will show you the results of this irresponsibility.

So in the beginning, may I state my opinion as condemning the practice of delegating the responsibility of the occlusal design of complete dentures to dental laboratory technicians and accept whatever may come, just like leaving the design of a cast partial denture to laboratory technicians. (44, 45)

I think now it is about time to express the main objectives of this experiment : It was to determine 1) Where did the stress trajectories locate in complete dentures, 2) Is there a significant difference in metal and plastic base dentures with porcelain teeth in relation to balanced and nonbalanced articulation.

MATERIALS AND METHODS

This preliminary study was undertaken in 4 patients. The artificial teeth used were porcelain and in cusped form for all cases.

The first patient whom I have concentrated this experiment was 51 years old male and a denture wearer for about 5 years.

The mucostatic technique was applied in impression making and the chromium alloy bases were constructed for the upper and lower master casts which were later covered by a very brittle enamel material (Lining enamel) as the factory (*) was reported.

(*) Emayetaş. İstanbul. Turkey

The vertical dimension of occlusion was determined according to Silverman's phonetic and Niswonger's two dots methods. The centric relation record was determined in soft bite waxes by swallowing.

The denture was prepared in the Dentatus articulator, only transferring the vertical dimension of occlusion and the centric bite. No other records were made and transferred to the articulator. In other words, the Dentatus articulator was used as a hinge-type articulator as most of the technicians use in their practice.

The cusped porcelain teeth were used and set in a flat plane. Care did never exercise to achieve protrusive as well as bilateral balanced articulation.

After waxing the case, the four plaster indexes were taken from the both parts of upper and lower dental arches including the occlusal surfaces of teeth to insure that no positional changes were incorporated when applied self curing acrylic resin.

After boiling out the wax, the artificial teeth were imbedded in their places in the plaster indexes and attached to the metal base by autopolymerizing methyl methacrylate. To secure the retention of teeth, the metal base had retentive loops along the alveolar crest.

Upon polymerization of the self curing acrylic resin, the polishing was proceeded and completed dentures were tried in the mouth. I will call this Case No : I A.

Then, the chewing tests were made to demonstrate and evaluate the stress trajectories. For that, the patient was planned to be given roasted peanut. However, in some cases raw carrot was also included into the chewing tests. The patient was also suggested to chew on either side or both, any manner which seemed most comfortable for him until he felt it was time to swallow and we let the patient to swallow. The dentures were the taken from the mouth, rinsed with tap water thoroughly and inspected with magnified glass to see the cracks on the base.

Since no cracks appeared, it was decided to leave the dentures in the mouth for two days. Still no cracks appeared.

This time, I have tried to find a more brittle material which can be cracked under force. At the end, I have decided to use a special kind of synthetic resin which is a substitute of the natural resin, called Colophane, and a kind of petroleum residue. I have melted the

resin in a cup mixing slowly and taking care of not to burn it. I then applied it on the base with a brush, not thinner than 1 mm. and flamed to obtain a smooth surface. The thickness of the lacquer coat was also measured. Then the dentures were dipped into the water to make them cold slowly since dipping then into a very cold water suddenly caused the resin to crack due to the contraction of the material. The cracks appeared were then photographed or recorded schematically.

To repeat the same test, the same metal base denture was balanced. To do that, the dentures were inserted into the patient's mouth and protrusive record was determined following the face-bow transfer. The lateral inclination of condyles were set in 15° degrees in the articulator as suggested by Gysi. Then the selective grinding was done for all the excursions of the mandible. The dentures were again inserted into the patient's mouth and selective grinding with the abrasive paste was completed. So we had a balanced articulation for all the eccentric movements of the jaws. I will call this case No: I B.

Then, the chewing test with peanut was made and the cracks appeared were photographed or recorded schematically.

In order to see the cracks better over a dark base, a new denture was constructed with methyl methacrylate dyed with aniline in powder form. However, when the flasks were opened, we have seen the base to lost its rigidity and become plastic in nature. In this case, we have decided to leave this attempt out.

For the same patient again, a plastic base denture were constructed in nonbalanced articulation first, which I will call this Case No : II A.

After finishing the dentures, the chewing tests with carrot and peanut were completed and recorded accordingly. Then, the same denture was balanced (Case No : II B) just like before and tests were again repeated and photographed or recorded schematically. Wondering if the direction of cracks will ever change, the chewing test with peanut was repeated a few days later in nonbalanced articulation before the case was balanced.

Three more patients whose dentures were constructed by the senior students in the Faculty were also included into this study selecting at random. These dentures were made with plastic bases and

porcelain teeth that their balances were not perfect at all, except the case No : III. The chewing tests were again performed with the same foods and the findings were recorded schematically. I will also call these Cases No : III, IV and V.

To summarize, please look at Table : 1

Mr. AHMET PEHLIVAN	METAL BASE Case No. I	A. NONBALANCED ARTICULATION A. NONBALANCED ARTICULATION
	PLASTIC BASE Case No. II	B. BALANCED ARTICULATION B. BALANCED ARTICULATION
Mr. TAHİR TÜZ. Case No. III. Plastic base. Balanced articulation		
Mr. MEHMET TOPAL. Case No. IV. Plastic base. Nonbalanced articulation		
Mr. DİKRAN KIZILOĞLU. Case No. V. Plastic base. Nonbalanced articulation		
<p>All the artificial teeth used were porcelain and cusped in form for all cases. Chewing tests were done either peanut or carrot, or both.</p>		

FINDINGS

Case No. I A. Mr. Ahmet Pehlivan

Metal base, porcelain teeth, nonbalanced articulation.

Chewing test with peanut

In the upper denture, the cracks appeared were all in the horizontal direction. There was one crack in the palate; another one was in the buccal flange way down the second molar, and another two small ones at the distal of the second molar toward the end of the denture. All these cracks were on the left side. There was another horizontal crack at the right side and it was on the buccal flange near the first molar.

In the lower denture, there was one crack at the labial flange almost vertical to the long axis of the first incisor on the left side, and a bunch of very thin horizontal cracks at the lingual side between the second bicuspid and the first molar near the periphery of the denture on the left side again.

Observations revealed that this patient seemed to be in the habit of chewing on his left side, and when asked he told the same thing.

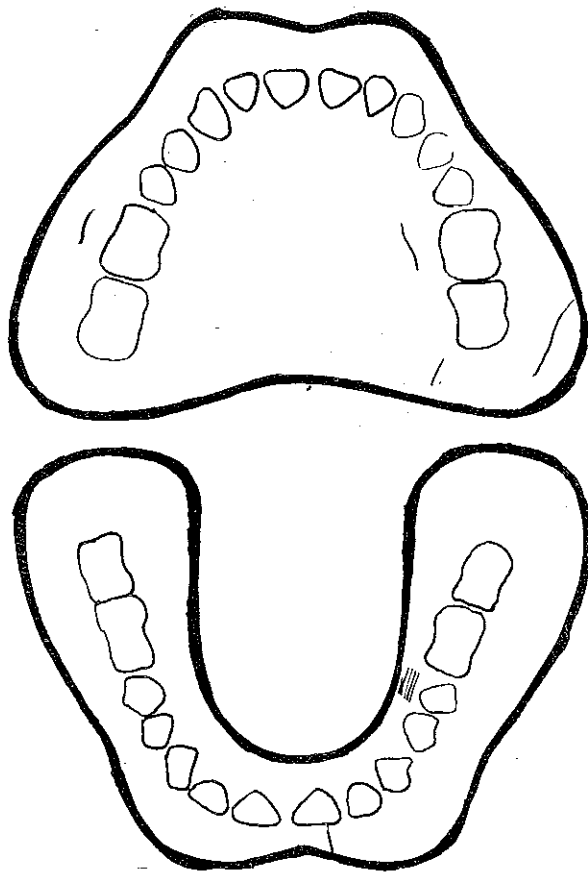


Fig. 5
CASE I A
Metal base, Porcelain teeth, Nonbalanced articulation
Chewing test with peanut

Case No. I B. Mr. Ahmet Pehlivan
Metal base, porcelain teeth, balanced articulation
Chewing test with peanut

In the upper denture, there were only two cracks crossing the palate almost horizontal to each other in the bicuspid area. There was another diagonal crack in the buccal flange near the second molar on the left side.

In the lower denture, there was no crack at all.

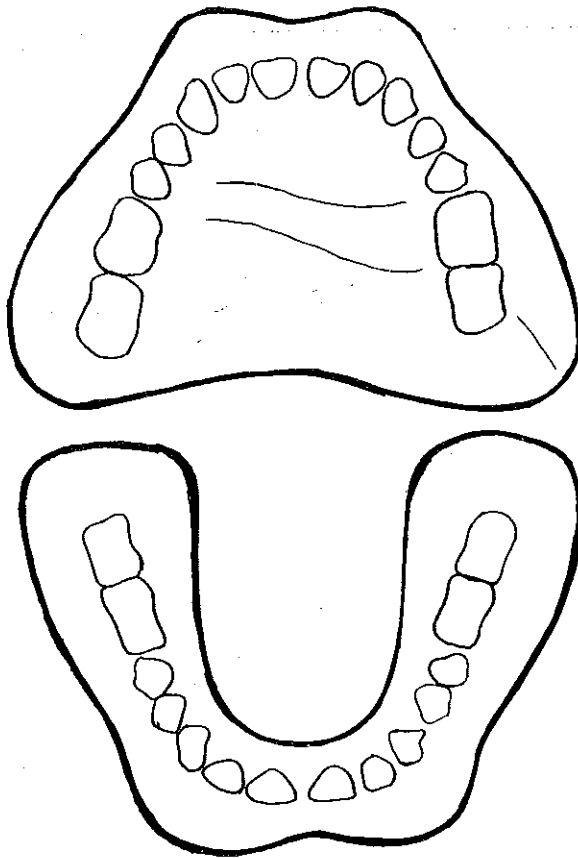


Fig. 6
CASE I B
Metal base, Porcelain teeth, Balanced articulation
Chewing test with peanut*

Case No I B. Mr. Ahmet Pehlivan
Metal base, porcelain teeth, balanced articulation
Chewing test with carrot

In the upper denture, there were short cracks on the palate in different direction around the midline. Another two cracks at the end of the second molars on both sides, and another one on the right side vertical to the cuspid in the labial flange.

In the lower denture, there were two cracks on the labial flange, one at the left and the other at the right side almost vertical to the second incisors. There were a few more cracks on the lingual flange near to the first and the second incisors on the left side.

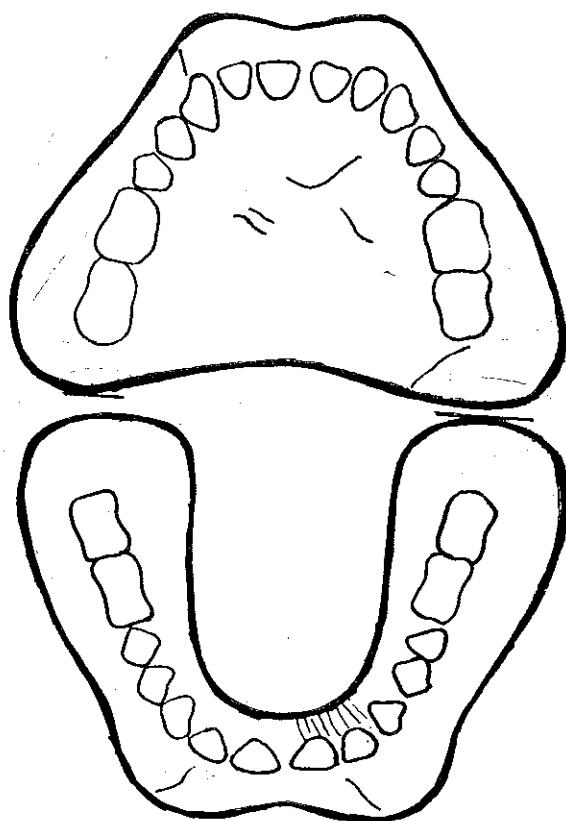


Fig. 7

CASE I B

Metal base, Porcelain teeth, Balanced articulation
Chewing test with carrot

Case No. II A. Mr. Ahmet Pehlivan
Plastic base, porcelain teeth, nonbalanced articulation
Chewing test with carrot

In the upper denture, the cracks appeared were located on the left side. In the buccal flange, there were diagonal cracks on the area of the second bicuspid and the first molar. In the palate, and again on the left side there were horizontal cracks in the bicuspid and molars regions almost horizontal to the dental arch as well as to each other.

In the lower denture, there were vertical cracks on the buccal flange in the left side, vertical to the long axes of cuspid and the first bicuspid. The cracks on the lingual side of the incisor region from cuspid to cuspid were diagonal in direction and these cracks were cutting each other quite regularly.

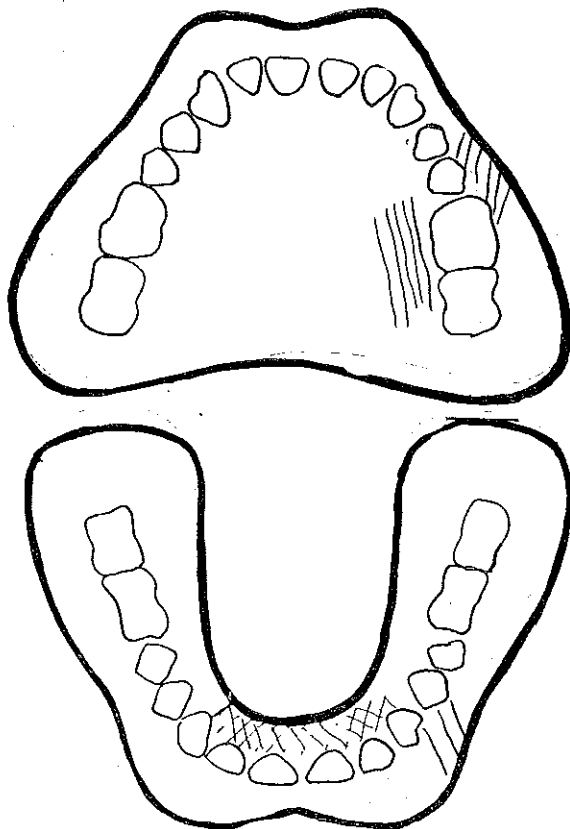


Fig. 8
CASE II. A
Plastic base, Porcelain teeth, Nonbalanced articulation
Chewing test with carrot

Case No. II B. Mr. Ahmet Pehlivan

Plastic base, porcelain teeth, balanced articulation

Chewing test with carrot

In the upper denture, there was no crack at all.

In the lower denture, the cracks appeared were located in incisor region; Both on the labial and lingual flanges. The cracks on the labial flange were vertical and in direction of long axes of teeth from cuspid to cuspid. In the lingual flange cracks were cutting each other diagonally as in the Case No. II A.

The chewing test with peanut in the Case No. II A, that is; plastic base, porcelain teeth and nonbalanced articulation has been repeated twice with a few days interval :

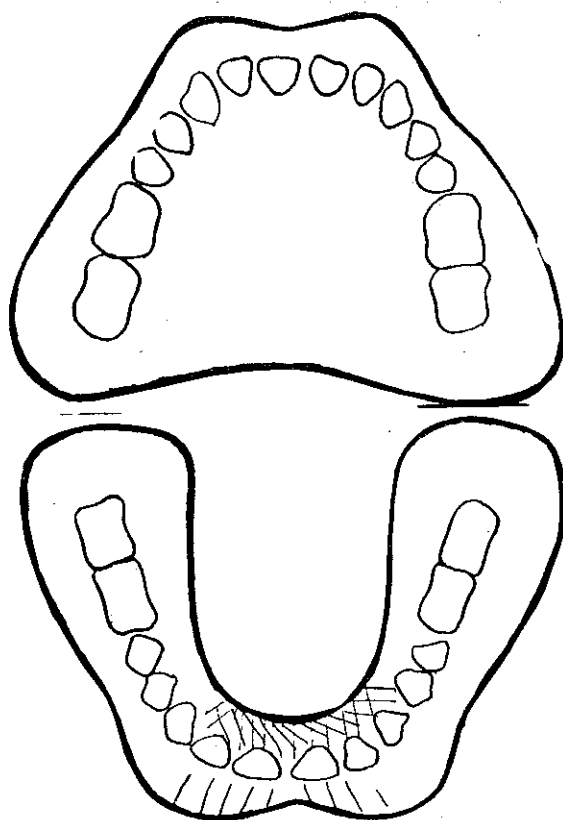


Fig. 9

CASE II A

Metal base, Porcelain teeth, Balanced articulation

Before a few days :

In the upper denture, the cracks were mainly located on the left side. There were vertical cracks on the buccal flange at the second bicuspid area and especially on the first molar region. The cracks on the palate were in horizontal direction parallel to each other as well as the dental arch. There were also a few more cracks on the plastic base.

In the lower denture, the cracks were mainly located on the lingual flange from cuspid to cuspid. These were cutting each other diagonally and quite regularly. There were cracks on the left buccal flange going diagonally from the first molar region as well.

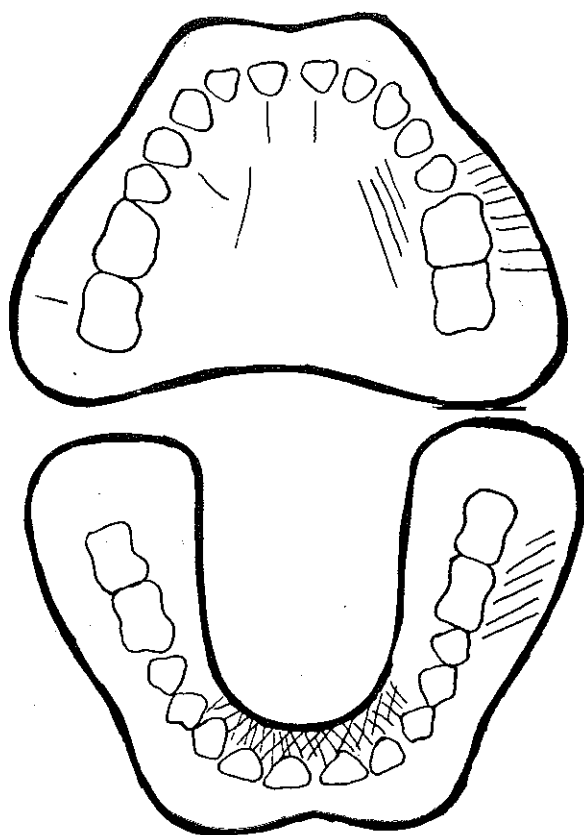


Fig. 10
CASE II A
Plastic base, Porcelain teeth, Nonbalanced articulation
Chewing test with peanut
Before a few days

After a few days :

In the upper denture, the cracks on the left side were almost the same as it was a few days earlier. But the cracks on the palate were a bit irregular. In addition, there were two short cracks at the end of the denture, distal to the left second molar.

In the lower denture, the same types of cracks appeared on the lingual flange from cuspid to cuspid. Also, there were vertical cracks on the labial flange in the first incisor and cuspid area as well as the diagonal cracks on the buccal flange in the second bicuspid and the first molar region. There were another two horizontal cracks, parallel to each other on the lingual flange between two molars.

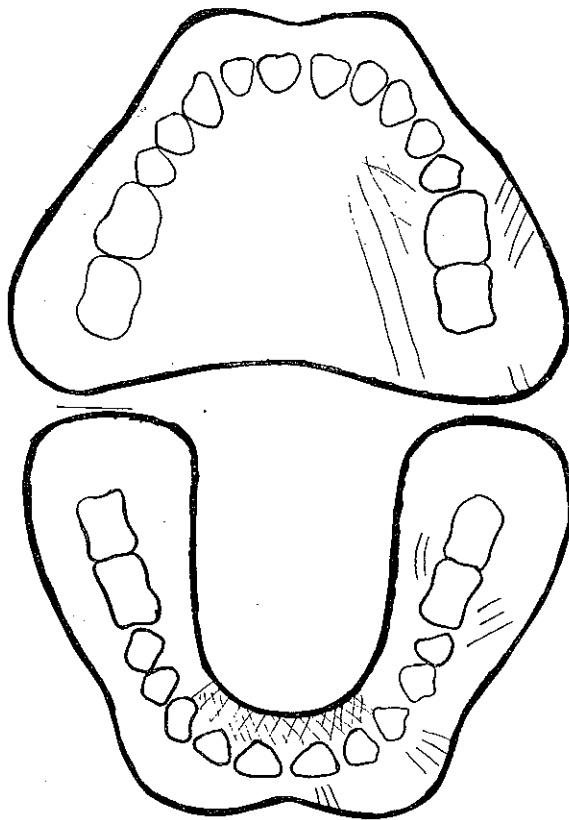


Fig. 11
CASE II A
Plastic base, Porcelain teeth, Nonbalanced articulation
Chewing test with peanut
After a few days

Case No. III. Mr. Tahir Tüz

Plastic base, porcelain teeth, balanced articulation

Chewing test with peanut

In the upper denture, the same types of cracks appeared on the right side in the palate, that was the diagonal cracks in «before» and «after» tests, as in the case No: II A The cracks at the posterior end of the denture were longer than in chewing carrot. Also, there were vertical cracks on both sides of the buccal flanges in the bicuspid region.

In the lower denture, there were diagonal cracks on the buccal and the lingual flanges in the first molar area. Also, there were a few vertical cracks on both sides of buccal flanges again, in the bicuspids regions.

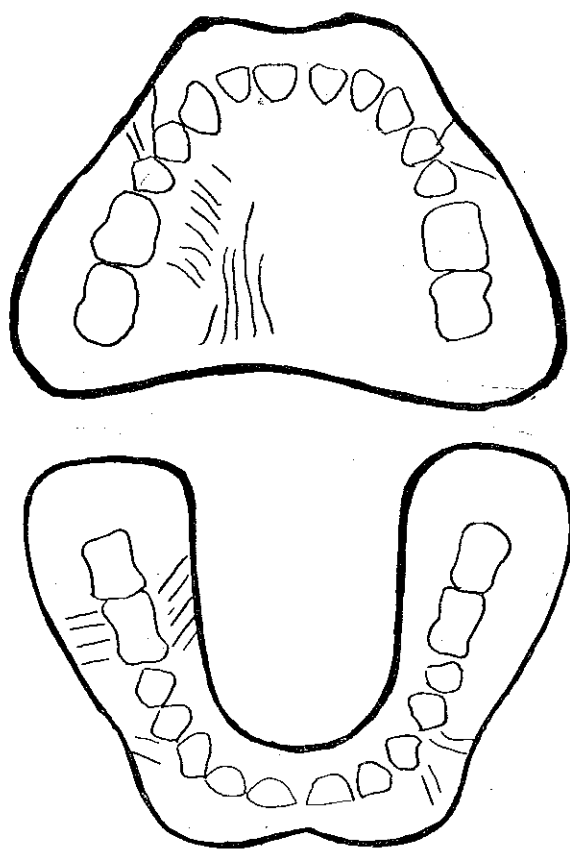


Fig. 12

CASE III

Metal base, Porcelain teeth, Balanced articulation
Chewing test with peanut

Case No. III. Mr. Tahir Tüz

Plastic base, porcelain teeth, balanced articulation

Chewing test with carrot

There were diagonal cracks on the palate in the first and second bicuspid and first molar region. Also, there were a bunch of short cracks at the posterior end of the denture. All these cracks were on the right side. There was another cracks on the labial flange, vertical to the left cuspid.

In the lower denture, there was only one diagonal crack starting from the cuspid on the labial flange in the right side.

When asked, this patient told that he can chew on either side properly and comfortably. However, the observations revealed that he seemed to prefer to chew on his right side.

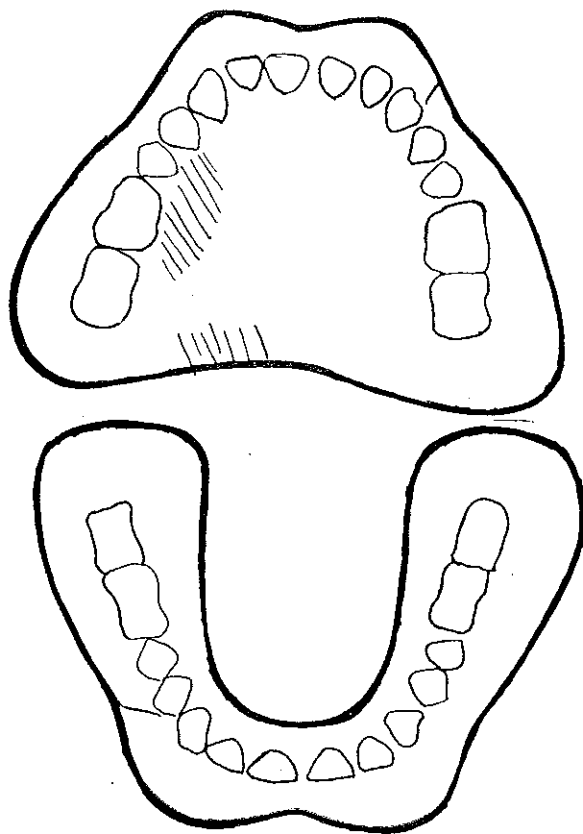


Fig. 13

CASE III

Metal base, Porcelain teeth, Balanced articulation

Chewing test with carrot

Case No. IV Mr. Mehmet Topal

Plastic base, porcelain teeth, nonbalanced articulation

Chewing test with peanut

In the upper denture, there were diagonal cracks on the right side in the molars area mainly on both buccal and palatal region. There were also horizontal cracks at the posterior end of the denture intermixing with the palatal cracks as well as some more cracks at the distal of the second molar on the same side.

On the left side, there were diagonal cracks at the second bicuspid and molar region on the buccal flange and some short cracks at the distal of the second molar on alveolar crest. Also, a bunch of short cracks appeared at the frenum area between the first incisors on the labial flange.

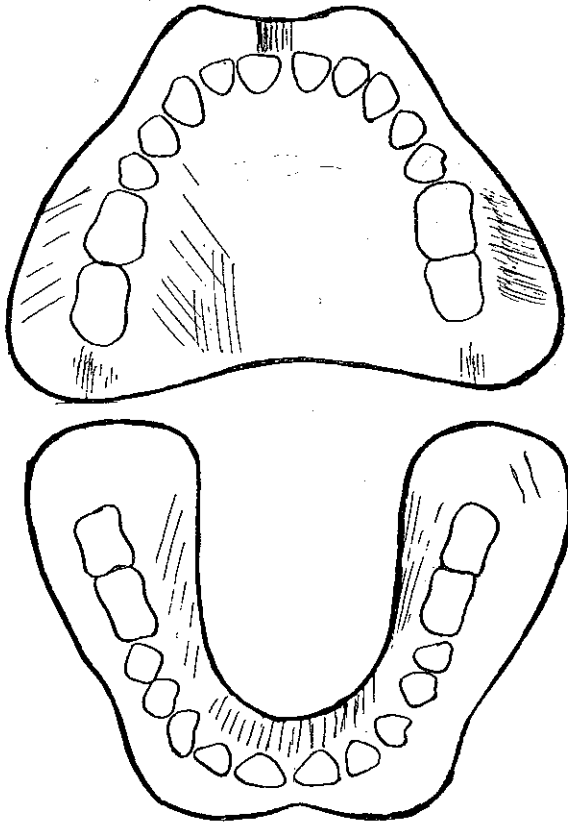


Fig. 14

CASE IV

Plastic base, Porcelain teeth, Nonbalanced articulation
Chewing test with peanut

In the the lower denture, there were vertical cracks parallel to the long axes of the teeth on the lingual flange from cuspid to cuspid. More cracks were also observed on the lingual side in bicuspid and molars region which were in diagonal or horizontal directin. In addition, two short cracks appeared at the distal end of the buccal flange on the left side.

Case No. V. Mr. Dikran Kızıloğlu

Plastic base, porcelain teeth, nonbalanced articulation

Chewing test with peanut

In the upper denture, there were a few horizontal cracks almost parallel to each other on the rugae area in the palate; two short diagonal cracks on the left side in the palate starting from the mesial of the first molar. Also, a few more diagonal cracks appeared on the

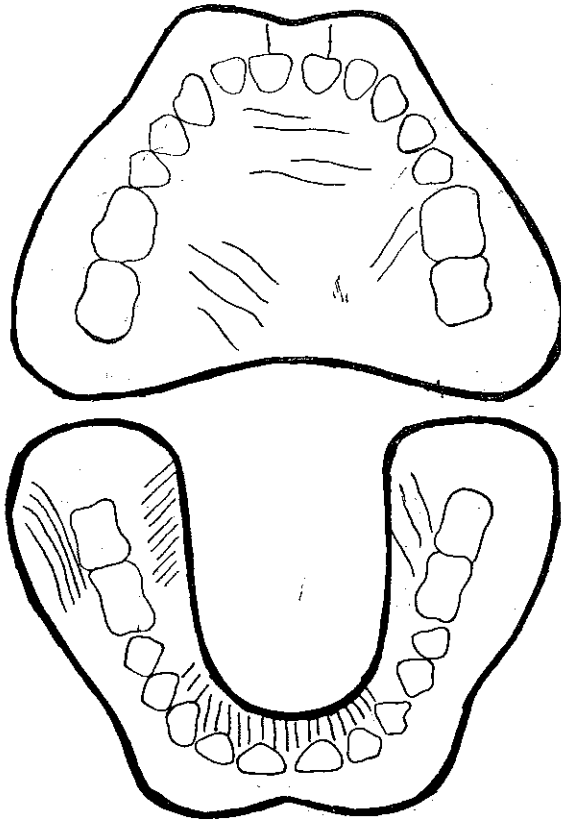


Fig. 15

CASE V

Plastic base, Porcelain teeth, Nonbalanced articulation

Chewing test with peanut

right side at the direction of first molar mainly toward the posterior end of the denture. At the same time, there were two vertical cracks on the labial flange parallel to the long axes of the first incisors.

In the lower denture, there were vertical cracks on the lingual side from cuspid to cuspid; the diagonal cracks on the lingual flange at the molar region on the right side and less cracks in number

		lower denture					
		Labial Flange	Right Buccal Flange	Left Buccal Flange	Lingual to incisors	Lingual to right molars	Lingual to left molars
METAL BASE case I	Nonbalanced Articulation A peanut	+	-	-	-	-	+ +
	Balanced Articulation B	-	-	-	-	-	-
PLASTIC BASE case II	Nonbalanced Articulation A carrot	-	-	+ +	⊕ ⊕ ⊕ ⊕	-	-
	Balanced Articulation B	-	-	+ +	⊕ ⊕ ⊕ ⊕	-	-

Table 2 : This is the comparison of metal and plastic base dentures. In the lower dentures, there is one thing to be noticed that the cracks are mainly located on the left side in plastic base dentures with nonbalanced articulation. Because patient's chewing habit was on the left side.

on the other side in the same area. On the left side, there were horizontal cracks on the buccal flange, almost parallel to the dental arch.

In the tables below, the findings will be presented thoroughly. The negative signs indicate no cracks. The positive signs indicate cracks. The more positive signs mean more cracks are located in the particular area. The five positive signs in circles indicate the diagonal cracks on both direction, almost parallel to each other on the lingual side of the lower teeth from cuspid to cuspid.

		upper denture					
		Labial Flange	Right Buccal Flange	Left Buccal Flange	Ruqae Zone	Right side on the Palate	Left side on the Palate
METAL BASE case I	Nonbalanced Articulation A peanut	-	+	+	-	-	+
	Balanced Articulation B	-	-	+	-	+	+
PLASTIC BASE case II	Nonbalanced Articulation A carrot	-	-	+	+	+	-
	Balanced Articulation B	-	-	-	-	-	-

Table 3 : This is the same table for the upper dentures. The five positive signs in circles indicate the diagonal cracks as explained above.

Comparison of the same denture with peanut

	lower denture					
	Labial Flange	Right Buccal Flange	Left Buccal Flange	Lingual to incisors	Lingual to right molars	Lingual to left molars
BEFORE A FEW DAYS	—	—	+ + +	⊕ ⊕ ⊕ ⊕	—	—
PLASTIC BASE NONBALANCED ARTICULATION case II B						
AFTER A FEW DAYS	+ +	—	+	⊕ ⊕ ⊕ ⊕	—	+ +

Table 4 : This is the comparison of the same plastic base dentures in nonbalanced articulation with a few days interval when chewing peanut. In the upper denture, cracks are mainly located on the left side due to patient's chewing habit.

Comparison of the same denture with peanut

	upper denture					
	Labial Flange	Right Buccal Flange	Left Buccal Flange	Ruqae Zone	Right side on the Palate	Left side on the Palate
BEFORE A FEW DAYS	—	+	++++	+	+	++++
PLASTIC BASE NONBALANCED ARTICULATION case-II B						
AFTER A FEW DAYS	—	—	+++	—	—	++++

Table 5 : This is the same experiment for the upper denture. The five positive signs also indicate the diagonal cracks as explained above.

	upper denture					
	Labial Flange	Right Buccal Flange	Left Buccal Flange	Ruqae Zone	Right side on the Palate	Left side on the Palate
Mr. Mehmet Topal case:4	+ + +	+ + + +	+ + + + +	-		-
Mr. Dikran Kızıloğlu case:5	+ +	-	-	+ + +	+ + +	+ +

Table 6 : This shows the two different upper dentures in non-balanced articulation. In this table one thing is quite clear that in one denture the cracks are mainly located on the vestibular flange whereas in other, mainly on the palate.

	lower denture					
	Labial Flange	Right Buccal Flange	Left Buccal Flange	Lingual to incisors	Lingual to right molars	Lingual to left molars
Mr. Mehmet Topal case:4	-	-	-	+ + + + +	+ + +	+ + +
Mr. Dikran Kızıloğlu case:5	-	+ + +	-	+ + + + +	+ + + + +	+ +

Table 7 : This is the same experiment for the lower dentures. Here, the cracks are mostly seen on the lingual sides.

		lower denture					
		Labial Flange	Right Buccal Flange	Left Buccal Flange	Lingual to Incisors	Lingual to right molars	Lingual to left molars
BALANCED ARTICULATION	Mr. Ahmet Pehlivan case II B	+ +	-	-	+ + + on the left	-	-
	Mr. Tahir Tüz case III	+	-	-	-	-	-

		upper denture					
		Labial Flange	Right Buccal Flange	Left Buccal Flange	Ruqae Zone	Right side on the Palate	Left side on the Palate
BALANCED ARTICULATION	Mr. Ahmet Pehlivan case II B	+	-	-	+ + in the middle of the palate	-	-
	Mr. Tahir Tüz case III	+	-	-	-	+ + + +	-

Table 8 and 9 : These two tables show the upper and lower dentures of two different patients in balanced articulation. The cracks in balanced articulation seem not as much as in nonbalanced articulation.

DISCUSSION

In the field of scientific research one can make any kind of investigation on animals, in laboratories or in human beings. Laboratory studies are not the same when applied to humans since human beings have a unique mechanism that you can never duplicate in laboratories. However, much can be gained from these studies. The same may not be true for animal experiments. But there are still some differences between animals and human beings. For that, if there is not a contraindication it would be advisable to study the variables in humans. That is the reason why I have chosen to study the stress distribution in patients.

Trapozzano (38) states that «one of the main difficulties with which we are confronted in complete denture prosthodontics is the scientific evaluation of so-called «basic concepts» or techniques. The need for controlled studies is manifest. Without controlled studies, many of our concepts and techniques will continue to be based on empirical evaluations placed upon by the individuals who are frequently stating opinions, and not necessarily facts.», that is, why all the research workers realize that for an investigation to be valid, the thing being tested could be the only variable. In order to accomplish this result, everything must be identical except the thing being tested. While this experiment is not that kind of a controlled study, I do only hope that this may help some further studies and stimulate the investigators to undertake a series of controlled studies in this field. Actually, in literature, there are many investigations like this which give a general idea of the problem involves.

So in discussing this paper, we must always keep in mind that from this experiment some general conclusions only will be drawn since in this experiment the below mentioned variables are not taken into consideration :

1. Vertical dimension of occlusion
2. Thickness of denture base
3. Setting artificial teeth on wider or narrower arch
4. Plastic and porcelain teeth in a common base with balanced and nonbalanced articulation
5. Bucco-lingual width of teeth
6. Antero-posterior length of teeth
7. Cusped, flat-plane and Centrimatic teeth
8. Different degrees of chewing force measured by an instrument

I believe the profession will answer these questions by means of controlled, clinical studies.

The physical properties of oral restorations must be adequate to withstand the stresses applied by the repetitive forces of mastication. This is what we call the strength of the material. The previous investigation (43) revealed that the metal base dentures were 8.5 times more resistant to lateral deformation than the plastic base dentures while undergoing the forces of mastication. In my study **the appearance of no cracks, or I'd better say, less cracks in the metal base denture may be attributed to the strength of the metal base under the chewing force.** Fig. 5,6,7. So this finding may be considered in accordance with Regli and Kydd's study (43). **That means an edentulous patient may not exert an extreme force to deform the metal base in his daily diet.** That's why the stress trajectories are not seen, or vaguely seen on the metal base. **Or to exhibit the trajectories much sensitive devices are necessary as Regli and Kydd (43) used which the human eyes can not see.** Also, the enamel covered the metal base may not be brittle enough and this may contribute the enamel not to be cracked. In any case, metal base dentures can be constructed thinner than plastic base dentures concerning the resistance to deformation. A metal base denture also satisfies the requirement of developing an interfacial surface tension in mucostatic technique, and at the same time it makes the patient comfortable by creating more tongue space as Trapozzano (38) mentioned. All these helps the adaptation of metal base much better to the underlying tissues and this may also help to develop less cracks in the enamel. There seems not to be much difference between types of foods within the limits of average biting force so far as the chewing stresses are concerned. I have the inclination to believe this is the case in metal base dentures.

In chewing test with plastic base dentures, I found one thing was quite clear that the stress trajectories were mainly concentrated on the side where the patients performed their chewing acts, since the plastic bases are not too resistant to deformation. When the patient bites down on any tooth, the cracks seemed to appear on that biting side since more force was exerted.

Balanced and nonbalanced articulation due to cuspal interferences which cause to initiate more forces, metal and plastic base due to close adaptation to the underlying supporting tissues and the

degree of chewing force seem to contribute the number of cracks to locate.

If the denture has an adequate balance, the cracks will be seen, if any, mostly on buccal flange where mastication has occurred, because a large surface on the palate as well as the thickness of the base near the artificial molars may absorb the stresses induced by the chewing force more easily and this may result less cracks on this particular area. However, if there are palatal cusp interferences the cracks may be observed on the palate too, (Fig. 11) or wherever the cusp interferences are. The number of lateral strokes during the course of mastication may also help the accumulation of stresses, especially in nonbalanced articulation.

The physical properties of food used in the tests in plastic base dentures, may also contribute the accumulation of stresses. For example, carrot may absorb the impact of chewing forces and this prevents the chewing force transferred directly to the base. (Fig. 13) On the other hand, peanut which is a brittle material may transfer the chewing force directly to the base and causes more stress accumulation in the area chewing. This may exhibit itself as more cracks on the surface of the resin. (Fig. 14) However, the physical properties of foods are not much to be considered since the balance of the denture, the structure of base, whether it is metal or plastic and the the degree of chewing force exerted by the patient account more in this field.

The resin to be coated the denture base should also be thick enough and cold enough to be cracked. Because when I applied the resin thinner and inserted the dentures in patient's mouth making it cold, it did not show any cracks whatsoever.

I also thought that the clear acrylic base coated with darkly dyed resin might produce better results so far as the exhibition of cracks are concerned or vice versa; that is, a darkly dyed acrylic base coated with clear resin. When I attempted to the methyl methacrylate to do so, the denture base became plastic upon removal them the flasks. The dying agent caused a kind of plasticity in the resin, and this prevented it cracking under the chewing force due to its plasticity. These observations have been before starting the experiment in Case No. I; However, it may be a way to prevent the dying agent to soften the acrylic base.

If everything is right, but the strength of coating resin is higher

than the patient's chewing force it would not be expected the resin to be cracked. This is understandable. Because the number of cracks seemed to be proportional to the degree of chewing force, and reversely proportional to the strength of coating resin.

I believe one of the most interesting findings in this study is the diagonal cracks in both directions cutting each other quite regularly on the lingual side of lower dentures from cuspid to cuspid (Fig. 8, 10). In the search of what caused this pattern, I made a test : I took a lower denture and coated it with the resin. I then took it with the fingers of my both hands, twisted one side down and the other side up; and vice versa, a couple of times. The same pattern has been shown in the same area. Then, I thought if the same movement would ever be possible in the mouth? Why not. If the denture has nonbalanced articulation providing a cusp rise at the back in balancing side and the patient performed his chewing on both sides, the lower denture can easily make this very same movement due to the resiliency of the soft tissues and the cusp rises. Actually the dentures which showed this pattern of cracks had nonbalanced articulation, the patients were chewing on both sides as a habit and the soft tissues covering the residual alveolar ridges on either side were quite compressible.

Also, in two lower dentures the cracks on the same side were vertical in direction almost parallel to the long axes of the teeth as well as to each other (Fig. 14). This may result of lower denture pushed forward during chewing and the alveolar ridge as a fulcrum point due to improper selective grinding or no grinding at all. Actually, this pattern of cracks also appeared in dentures with nonbalanced articulation.

So, the difference in thickness of the denture base, the chewing force exerted by the patients, balanced and nonbalanced articulation as well as the lateral strokes associated with nonbalanced articulation may all contribute the types of cracks in length and in direction. These may also help the number of cracks to locate. That's why in two patients the same types of cracks may not be seen in the same area.

In one patient, the tests with peanut have been repeated twice with a few days intervals, and the cracks seemed to locate mainly in the same area where the patient chewed (Fig. 10, 11). It was expected, because the patient's chewing pattern did not change. However, the other cracks in «after» case may be caused by the

patient to chew more vigorously at that time causing more external force to deform the base.

Certainly as important as the measurement of forces and stresses in dental structures is the use of this information in determining the design of a restoration (21). Since the metals used in the mouth have enough strength, it is not necessary to give a special care to the design of the base. Metal base dentures can safely be constructed thinner than the plastic base dentures. But when having fabricated a plastic base denture, care should be given to the thickness on the bicuspid and molars region to withstand the stresses induced by the chewing force. Because patients usually chew their foods on the second bicuspid and the first molar. Since these are primary stress bearing areas, in order to prevent the base to deform, the thickness should be increased. The space of Donders as well as the proper room for the tongue may of course be the limiting factors. If the balanced articulation and the close adaptation of the base to the underlying supporting structures are to be achieved, the thickness of the denture base may be reduced.

Finally, I must emphasise that the results mentioned here are not statistically valid as only a few cases were used in this study.

CONCLUSION

In summarizing the paper, I would like to repeat my opinions shortly: I believe as a dentist, we must be careful about the below-mentioned points when constructing a complete denture.

1. If there is not a contraindication it would be advisable to use a metal base for the proper distribution of chewing stresses and to withstand the force exerted by the patients during mastication.
2. I feel that dentures constructed on an adjustable articulator according to the laws of articulation may be better than the ones constructed on a hinge-type articulator concerning the stress distribution. In other words, full balance seems to be the requisite for evenly distribution of chewing stresses.
3. Dentures exhibit more stress trajectories on the chewing side, especially in plastic base dentures with nonbalanced articulation. This is directly related with the external force applied.
4. In nonbalanced articulation, there will mostly be a unique pattern of cracks in the lingual side of the lower incisors from cuspid to cuspid. This may be due to specific movement of the denture base during mastication.

5. Since this is an uncontrolled study, I only stated here before you, the distinguished audiences, my personal observations and tried to reach to certain conclusions which may not be based on scientific evaluations, and I only hope to stimulate some further studies in this field.

Thank you for your kind attention.

My sincere appreciation is expressed to Dr. Babür Canikoğlu in the department of crown and bridge, University of Istanbul, Faculty of Dentistry, for his invaluable help in this study.

Ö Z E T

TAM PROTEZLERDE STRESS DAĞILIMI

Bu araştırma tam protezlerde stress dağılımını inceleyebilmek için yapılmıştır. Ayrıca aynı araştırmanın bir yan çalışması olarak da metal protezlerle akrilik protezler arasında, stress dağılımı bakımından bir fark olup olmadığı da dikkate alınmıştır. Yine bu çalışmaya ilâve olarak balanslı ve balansız tam protezlerde stress dağılımının farkları da incelenmiştir.

Stress dağılımı tam protezler üzerine, Colophane denilen tabii reçinenin yerine kullanılan özel bir çeşit sentetik reçinenin ısıtılarak eritilmesi ve 1 mm. kalınlıkta olmak şartıyla fırçayla sürülmesi ile yapılmıştır. Hastalara çiğneme testlerinde fıstık ve havuç yedirilmiş ve ağızdan alınan protezlerin hangi bölgelerinde reçinenin kırıldığı gözlenmiştir. Bu kırılmalar şematik olarak şekiller halinde gösterilmiştir.

Araştırmanın genel sonuçları şöyle özetlenebilir:

1. Stress dağılımı ve çiğneme basıncına karşı protezlerin daha başarılı olarak dayanabilmesi için, şayet herhangi bir kontrendikasyon yoksa, metal kaide plaklı protezlerin yapımı tavsiye edilir.
2. Protezlerin oklüzör üzerinde değil, bir artikülâtör üzerinde yapılması stress dağılımı bakımından daha uygundur. Zira balanslı bir artikülasyonda stress birikimi belirli bölgelerde toplanmamaktadır.
3. Özellikle balanssız ve akrilik protezlerde stress birimi, daha çok çiğneme tarafında olmaktadır. Uygulanan kuvvetle stress birikimi arasında doğru orantı vardır.
4. Balanssız artikülasyonlu protezlerde alt protezin ön tarafta dil bölgesinde bir birini muntazam bir şekilde kesen diagonal çatlaklar oluşmaktadır. Bunun nedeni balanssız artikülasyonda alt protezlerin spesifik bir hareketine bağlanabilir.
5. Kontrolsüz bir araştırma olan bu çalışmanın sonuçları kesin olarak değerlendirilmemelidir. Amaç tam protezlerde stress dağılımı konusunda yapılacak daha geniş çalışmaları teşvik edebilmektir.

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