

## AN INVESTIGATION OF FRACTURE LOADS OF ACRYLIC BASE PLATES REINFORCED, NON-REINFORCED AND PREPARED IN DIFFERENT PALATAL SHAPES

### FARKLI DAMAK ŞEKİLLERİNDE TAKVİYE EDİLEN VE EDİLMİYEN KAİDE PLAKLARININ KIRILMA KUVVETLERİNİN İNCELENMESİ

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#### ABSTRACT

*The purpose of this study was to evaluate the fracture resistance of reinforced acrylic denture base, using three different palatal shapes.*

*Maxillary denture bases having three types of palatal vault shapes –shallow, medium and deep– were used in this study. The reinforced materials used were the round metal wire-diametered in 1.50 mm, semi-rounded metal wire -thickened 1.50×0.75 mm- and the stainless steel mesh (70mm×2.5mm×2.5mm). A total of 132 acrylic denture bases were prepared with the conventional method from heat-cured acrylic resin (Meliodent; Heraeus Kulzer Ltd). They were stored in distilled water at 37±1°C for 48 hours before testing. After storage, the fracture force was measured by using Haunsfield pull-compress machine at a cross-head speed of 5 mm/min.*

*Standard deviations and means were calculated. Univariate variance analysis was used for statistical assessment. Duncan multiple-comparison test was applied.*

*In this study, fracture resistances of denture bases in shallow shaped (79.3 N) were found lower than those of the medium (86.8 N) and deep shaped ones (81.2 N). It was determined that the type of the palatal shapes and reinforcement would significantly affect fracture resistance.*

**Key Words:** *Palatal shapes, reinforced material, fracture loads*

#### ÖZET

*Bu çalışma, metal ile güçlendirilmiş ve güçlendirilmemiş olarak farklı damak şekline sahip modellerde hazırlanan akrilik kaide plaklarının kırılma kuvvetlerini incelemek amacı ile yapıldı.*

*Üç farklı damak şekline sahip modeller (sığ, orta ve derin) çalışmada kullanıldı. Her bir damak şekline 16 tane olmak üzere, toplam 48 model sert alçıdan elde edildi. 2.80 mm kalınlığında mum alçı modeller üzerine yerleştirildi. Modeller mufloya alındıktan sonra kuvvetlendirilmiş veya kuvvetlendirilmemiş olarak üreticinin önerisi doğrultusunda hazırlanan akrilik rezin ile akrilik kaide plağına dönüştürüldü. Hounsfield çekme-sıkıştırma cihazında 5 mm/min başlık hızı ile kırılma dayanıklılıkları tespit edildi.*

*İstatistiksel değerlendirme için varyans analizi kullanıldı. Ortalama ve standart sapmalar hesaplandı. Duncan çoklu karşılaştırma testi uygulandı. Kırılma mukavemetinin; düz damaklarda (82.31 N), orta (87.75 N) ve derin olanlardan (88.13N) daha düşük olduğu görüldü. Damak derinliği ve takviyenin önemli ölçüde kırılma kuvvetini etkilediği istatistiksel olarak saptandı.*

**Anahtar Kelimeler:** *Damak şekli, takviye materyali, kırılma kuvveti.*

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## INTRODUCTION

PMMA is the most commonly used material for denture base construction. However, its resistance to impact and its fatigue failure are somewhat poor. So fracture of acrylic resin denture bases is a continuing problem in prosthodontics. The ratio of maxillary to mandibular denture base fractures is 2/1 and mostly occurs as midline fractures. It was pointed out that the durability or original durability of fractured acrylic dentures as a result of repair was only at the rate of 40-71%.<sup>1</sup>

Even though acrylic base plates in total dentures were prepared suitably and occurred in a balanced occlusion, it was possible to meet the fractures in some circumstances. This, too, requires more resistant materials against traumatic stress, or chewing in order to cope with the failure completely.<sup>2,3,5-9</sup>

The existence of the fracture is inevitable in such situations as wearing out of acrylic base plates,<sup>3,9</sup> in traumatic situations such as falling down of the denture,<sup>2,3,5,10,11</sup> discords with supported tissue depending on alveolar resorption, occlusal disturbances, hard and soft tissue undercuts and wide relief area gone under acrylic base plates.<sup>3,12</sup> With the aim of prevention of the fractures occurring probably in acrylic base plates undergoing a number of flexibilities depending on shape and structure of the support tissues in long-term usage, in order to minimize the excessive pressure in median palatal suture, it is suggested that palatal relief should be done in the anterior area of the palate,<sup>2</sup> the sides of the dentures fitting in labial frenulum should be thickened,<sup>13</sup> and acrylic deformation and acrylic base plate should be reinforced.<sup>14-18</sup>

Metal wire or wire mash is commonly used as a reinforcing materials.<sup>19,20</sup> However metal dose not chemically bond to resins and the resin over the metal appears black.<sup>21,22</sup> Although several methods have been used to improve the adhesion between metal and resin, metal-reinforced dentures may be unesthetic.<sup>23-25</sup> Furthermore, metal rods and wire mesh have disadvantages in that handling and cutting is difficult.<sup>21,22</sup>

Many attempts have been made to enhance the strength properties of acrylic denture bases including the addition of metal wire.<sup>14,23-28</sup> In addition to this, various types of fiber including carbon fiber,<sup>15</sup> aramid fiber,<sup>16</sup> polyethylene fiber,<sup>14</sup> and glass fiber<sup>16-18</sup> have been used as reinforcement. Reinforcement with fibers enhances

the mechanical strength characteristics of denture bases.<sup>29</sup>

In most situations, fractures occur in the midline of the denture base. This location of fracture occurs more often in maxillary dentures than in mandibular dentures.<sup>30</sup> Morris et al<sup>10</sup> stated that downward force applied to the midline of denture intra-surfaces became equal to the one applied to upward force on the teeth in both sides, and they also stated that this was a sufficient test in upper dentures and it would be used in determination of the twisting force.

The purpose of this investigation was to evaluate the fracture resistance of reinforced acrylic denture bases, using three different palatal shapes.

## MATERIALS AND METHODS

In this in vitro study, maxillary casts of edantulous in three different types of palatal vault shapes as deep, medium and shallow were used. Dimensions of palatal shapes used in this study were showed in Table 1 and schematic representations of palatal shapes were showed in Figure 1. The three different type casts were duplicated with silicone impression materials (Speedex putty and lighth body, Coltene AG, Feldwiesenstrasse 20, 9450 Altstatten, Switzerland). A total of 132 acrylic denture bases were prepared in dental flask with duplicated dental stone casts (Bego Bremer Gold Schlagerei Herbst GmbH Co. Emil-sommer Bremen), each type of palatal shape groups had 44 acrylic denture bases.

Table 1. Dimension of palatal shapes used in this study (mm).

Types of palate shape	Palatal vault depth
Shallow	20
Medium	14
Deep	9

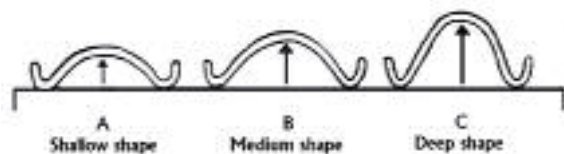


Figure 1. Schematic representation of type of palatal shapes.

In order to be able to provide the standardization of denture base thickness, a standard wax denture base (2 mm thickness) for each palatal shape groups was prepared. A denture base pattern was waxed up on one of the casts using standard modelling wax (De Trey Dentsply, Dentsply Ltd., England). Wax denture bases were duplicated with silicone (Speedex putty and ligh body, Coltene AG, Feldwiesenstrasse 20, 9450 Altstätten, Switzerland) and were used each time during flasking. Each assembly of waxed denture base and dental stone cast was conventionally flasked in plaster using a standard metal dental flask. After complete setting of gypsum, the two halves of the flasks were separated and the wax removed by standart boiling water procedures.

Round wire diametered in 1.50 mm, semi-round wire diametered in 1.50×0.75 mm and stainless steel mesh (70mm×2.5mm×2.5mm) were used in this study as reinforcement materials (Figure 2). After flasking, the metal wires were shaped and adjusted and were placed in palatal area frontally across the second premolar teeth region on the casts. The stainless steel mesh was covered completely of palatal area (Figure 3).

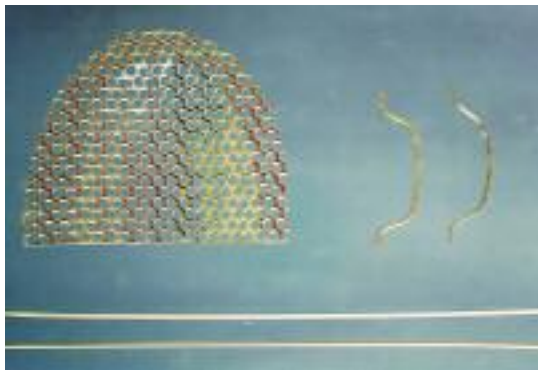


Figure 2. Reinforcement materials used in this study

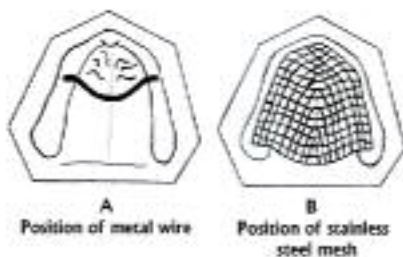


Figure 3. Schematic diagram of position of reinforcement materials.

The heat-polymerized acrylic resin (Meliodent; Heraeus Kulzer Ltd, RG 141 DL Newbury, Berkshire) polymer and monomer were mixed in accordance with the manufacturer's directions. Conventional packing and polymerizing procedures were used. After deflasked, the thickness of the dentures was measured by a digital caliper (Electronic Digital Caliper, China). Differences in dimensions were carefully eliminated by trimming the dentures to predetermined dimensions, and then abrasive wheels and silicone points were used to finish the dentures. The reinforcement materials were encased in acrylic resin to a depth of 1mm.

All denture bases were stored in water bath at  $37 \pm 1^\circ$  for 48 hours before testing. Acrylic denture bases were placed on the sub-table of the instrument so that the tissue surface of the bases was in the up direction. The load applied to the center of reinforcement area on midline of denture bases until catastrophic failure occurred (Figure 4). The fracture loading test was performed with Haunsfield pulling-compression machine at a crosshead speed of 5mm/min. The fracture resistance was calculated as Newton.

After data collection, mean values and standard deviations were calculated and compared by analysis of variance ( $p=0.05$ ) and multiply comparison (Duncan) test. The data were analyzed with statistical software program (SPSS Version10.0; SPSS Inc, Chicago).

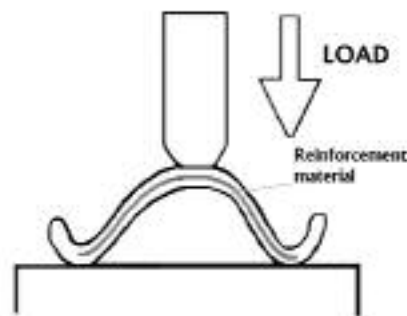


Figure 4. Schematic diagram of test method.

## RESULTS

The number of samples belonging to the examined factors and average results and standard deviations are shown in Table 2. The fracture resistances of denture bases reinforced with stainless steel mesh were found highest for all denture base shaped groups. Variance analysis used in the assesment

of the results indicated that reinforcement and type of the palatal shape would affect the strength of fracture considerably (Table 3). The statistical analysis showed that the differences were significant between types of palatal shape ( $p < 0.05$ ), and between reinforcement materials ( $p < 0.001$ ).

According to the multiple comparison test, it was showed that fracture resistance of denture base in shallow and medium shaped groups became different from each other and deep shaped became similar to all groups. It was also detected that fracture resistance of acrylic denture base reinforced with round or semi-round wire became similar, and reinforced with stainless steel mesh or unreinforcement group became different from these groups and each other ( $p < 0.001$ ) (Table 4).

Table 2. The mean values and standard deviations.

	Shallow		Medium		Deep		Total	
	N	Mean	St.d.	Mean	St.d.	Mean	St.d.	N
Un-reinforced	11	87.0	9.35	90.0	17.35	90.7	12.28	33
Stainless steel mesh	11	102.0	17.15	111.7	16.98	109.3	10.88	33
Round wire	11	66.8	5.13	74.6	19.93	57.1	11.15	33
Semi-rounded wire	11	61.7	5.95	71.0	15.56	67.6	11.80	33
Total	44	79.3	19.20	86.8	23.42	81.2	23.33	132

Table 3. Analysis of variance.

Source	df	Type III Sum of Squares	Mean Square	F value	Sig
Palatal Shape	2	13444.0909	6722.0455	3.657	< .05
Reinforced	3	393350.6061	131116.8687	71.333	< .001
Interaction (Palatal Shape X Reinforced)	6	14842.5758	2473.7626	1.346	
Error	120	220572.7273	1838.1061		
Total	132	9626460.0000			

Table 4. Duncan's test results.

Palatal Shape	1	2	
Shallow	79.3a		
Deep	81.2a,b	81.2b,a	
Medium		86.8c	
Reinforced	1	2	3
Round wire	66.2a		
Semi-rounded wire	66.8a		
Un-reinforced		89.2b	
Stainless steel mesh			107.6c

## DISCUSSION

According to this investigation result, unreinforcement acrylic denture bases were broken with smaller forces than reinforced with stainless steel mesh. Thus, we don't agree with the ideas of Smith<sup>30</sup> stating that the problem couldn't be solved by adding metal and fiber to the acrylic in order to increase the resistance of acrylic denture base. One of the proposals offered for strengthening the acrylic resins is to place the materials into acrylic denture base. The effectiveness of this may lead to discussions.<sup>2</sup>

John et al.<sup>16</sup> reported that the flexural strength of conventional acrylic resin, when the acrylic resin reinforced with glass, aramid or nylon fiber, improved. In acrylic resin reinforced with glass fiber, the force required to fracture ranged from 185 to 235 N, the flexural strength of these specimens ranged from 825.4 to 1048.5 MPa, highest among all groups. Kanie et al.<sup>31</sup> determined that the flexural strength of the unreinforced acrylic resin and reinforced with woven glass cloth acrylic resin were 68.6 MPa and 216.4 MPa. Kim and Watts<sup>18</sup> reported that the impact strength increased 224% at crack initiation and 290% at complete fracture when the denture was reinforced with woven E-glass fiber. In the investigation by Kanie et al.,<sup>17</sup> the flexural strength of denture base polymer reinforced with three silanize or unsilanize woven glass fiber was higher than unreinforced denture base. In addition, it was found that flexural strength and impact strength did not increase with increasing number of glass fiber.

In the researches indicating stress distribution in upper complete dentures, it was shown that the stresses concentrated on palatal region. In addition, it was pointed out that the stresses started from the zero in palatal of central incisors and reached at maximum in mesial of premolars, and was reduced to the zero again in distal of the second molars<sup>2</sup>. In this study, thus, the wires used as reinforcement materials were placed to the region where the stresses became dense in the direction of Ruffini<sup>5</sup>'s offers in such a way that it would be stiff in middle line.

The highest fracture resistance values were found 102 N in shallow, 109.3 N in deep and 111.7 N in medium palatal shaped of denture bases reinforced with stainless steel mesh. In addition, it was 87 N in shallow and 90 N in medium and 90.7 N in deep shape denture bases in unreinforced group. The lowest value was 61.7 N in shallow and 71 N in medium palatal shape reinforced with semi-round wire, and 57.1 N in deep palatal shape reinforced with round wire. Variance analysis showed that reinforcement type significantly affected fracture resistance ( $p < 0.001$ ).

The lowest fracture resistance value was obtained in round or semi-round wire reinforcement denture base. We concluded that the metal wires used gave a negative result, not positive. This result is in harmony with the ones of Darber et al.<sup>32</sup> and Caroll and von Frounhofer's.<sup>33</sup> In addition, it is very difficult to place metal wire accurately a reinforcement in the desired position in the denture base resin.<sup>34</sup>

Karaagaçlıoğlu et al.<sup>35</sup> stated that the most effective of reinforced materials they included in the research context were stainless steel mesh, three flex filament and aluminum mesh respectively. They concluded that the fact that stainless steel mesh showed more resistance than the aluminum and the fact that the porous in stainless steel meshes became wider than in the other ones would be due to performance of a more uniform structure of acrylic during polymerization.

Upper complete dentures depending on maxillary arch and palatal form are of geometric shapes, and include various concave and convex surfaces. There have been a small number of studies indicating that there is a relationship between flexibility endurance of acrylic base plate and palatal depth.<sup>10,15</sup> In this study, fracture resistance of acrylic denture bases prepared in shallow shape (79.3 N) were found lower than prepared medium (86.8 N) and deep (81.2 N) palatal shape

ones. The fracture resistance of denture base in medium or deep shaped were close to each other.

In the result of the studies carried out by Yesil<sup>36</sup> and Morris et al.<sup>10</sup> they stated that the fracture resistance of acrylic denture bases in shallow palatal shape became lower, while fracture resistance of denture bases became closer to each other. Karaagaçlıoğlu et al.<sup>35</sup>, examining fracture resistance of acrylic denture bases in different maxillary palatal structure, also detected that fracture resistance in shallow palatal shape became lower than those of medium and deep shape.

### CONCLUSION

From the result of this study, it was found that fracture forces of acrylic denture bases prepared in shallow shape became lower than those of medium or deep ones. The shape of palatal depth significantly affected on fracture resistance.

The highest results were obtained from denture bases reinforced with stainless steel mesh. The lowest results were obtained from denture base reinforced with round or semi-round wire. The results showed that denture bases reinforced with metal wire were not successful compared with the other groups. The stainless steel mesh reinforcement significantly improved the fracture resistance of acrylic denture base resin.

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