An „*in vitro*” Investigation on Retentive Characteristics of Acrylic Resin Overdentures with Bar/Rider Connection System

DIANA NAICHE[1], FLORIN TOPALA[1], ANCA JIVANESCU[1], EMANUEL BRATU[2], CARMEN TODEA[3]*

[1] UMF „Victor Babes” Timisoara, Department of Prosthetic Dentistry, 2 Eftimie Murgu Sq., 300041, Timisoara, Romania

[2] UMF „Victor Babes” TimisoaraDepartment of Oral Implantology and Implant Supported Prosthesis, 2 Eftimie Murgu Sq., 300041, Timisoara, Romania

[3] UMF „Victor Babes” Timisoara, Department of Oral Rehabilitation and Dental Emergency, 2 Eftimie Murgu Sq., 300041, Timisoara, Romania

The purpose of this „in vitro” study was to evaluate the retentive force of the bar/rider attachement system in 4 situation and to compare their fatigue behaviour after consecutive insertion-removal cycling.

Keywords: retentive force, bar/rider attachement system, fatigue

Implant overdentures are a well-established therapeutic option for edentulous patients that offer improved retention and stability over traditional acrylic resin dentures. A wide range of attachment designs for supporting prosthetic superstructures are now available through multiple implant manufacturers, but little data is provided about the retention value and the longevity of such connection systems.

The amount of denture retention directly influences the patient's satisfaction, as it has been reported through several studies. Using a cross-over experimental design, Burns et al. found a strong patient preference for attachments with superior retention[1]. In a cross-over clinical trial involving patients with overdentures using bar-and-clip, ball, and magnet attachment systems, the bar/rider system was shown to provide the greatest retention [3].

The selection of a certain type of connection system is dependent upon jaw morphology and anatomy, function, the amount of available space, load distribution to implants and mucosa, the angulation of the implants etc. A bar/rider system is useful, especially when implants are not parallel to each other. This method ensures that the path of insertion of two attachments is parallel regardless of the angulation of the implants[5]. The degree of retention of the attachment system[4], prosthodontic maintenance and complications, or patient compliance for recall are also important parameters to be taken into consideration. Loosening of the retentive mechanisms when using implant overdentures, has been identified as the most common prosthodontic complication (33%). Therefore, routine maintenance is required to ensure successful long-term outcomes [6, 7].

The wear of attachments is due to insertion/removal movements as well as functional load[8]. The fatigue of the connection system adversely affects the overdenture function or maintenance and patient satisfaction [9]. In a 5-year randomized clinical trial conducted by Naert et al.[10]where it was investigated the prosthetic outcome of mandibular hinging overdentures on different attachment systems, the conclusion was that the magnet and ball group had the highest incidence of prosthetic complications when compared to the bar/rider group. In this last group, the most common complication was the reactivation of the implant-supported overdenture clips unlike magnet group, where frequent renewal of magnets was necessary because of wear and corrosion, or the ball group, where tightening of the abutment screws and renewal of the O-rings were necessary [11].

Considering all these, it is appropriate to evaluate the retention of attachments in the post-insertion period. Connection system will serve little clinical purpose if due to fatigue it will loose its retention after few weeks. Therefore, fatigue behaviour is a critical characteristic of overdenture attachments[12].

Experimental part

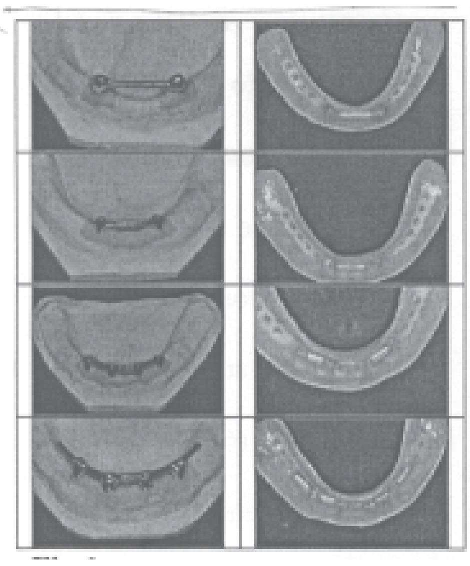
Materials and methods

Preparation of the bar

The situations presented in figure 1 were prepared following the same steps.

The implants (2 for the situations 1 and 2) and (4 for situation 3 and 4) were placed in an artificial mandible, in the interforaminal space, perpendicular to the occlusal plane with the aid of a parallelometer (table 2). Implant level impression (the same procedure as in the oral cavity) was taken using an individual open tray (Elite LC Tray, Zhermack, Rovigo, Italy) and polyeter material (Impregum Soft, 3M Espe, Seefeld, Germany). The final working cast with the analog implants (ISO Type IV dental stone, Elite-master, Zhermack, Rovigo, Italy) were done together with soft tissue replica (gingiva mask, Gi-Mask, Coltene Whaledent, Altstätten, Switzerland). The plastic copings (MD-CP013, Direct plastic cylinder without hex., MIS-Implants Inc., Shlomi, Israel) were placed on the analogs and tightened with screws. The plastic Dolder-type bars (MM-PBU10, Plastic bar-ovoid, MIS-Implants Inc., Shlomi, Israel) were cut and fit beetwen the plastic abutments or waxed copings (situation 1) without or with extension (situation 4) and connected using autopolymerizing acrylic resin (DuraLay, Reliance Dental, Worth, IL). The overdenture bars were obtained with conventional casting methods from Co-Cr Alloy (Brealloy MO, Bredent, Senden, Germany).

* *email:carmentodea@gmail.com*



Situation 1 : 2 implants splinted with a cemented bar + acrylic resin overdenture

Situation 2 : 2 implants splinted with a screwed bar + acrylic resin overdenture

Situation 3 : 4 implants splinted with a short bar + acrylic resin overdenture

Fig. 1. The situations with bar / rider connection systems

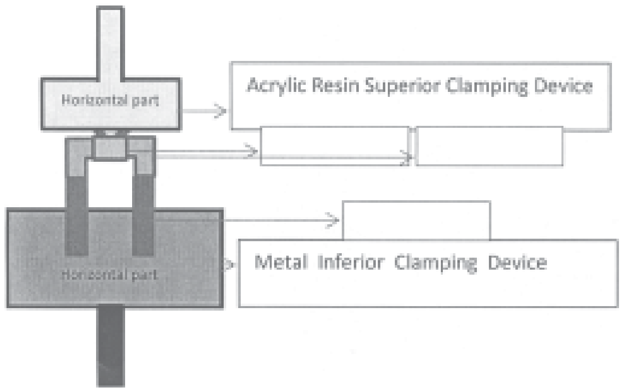


Fig. 2. Preparation of the clamping devices into the testing machine

Preparation of the attachments (riders/clips)

The riders selected for testing, were prefabricated gold riders (MM-GRU10, Gold rider-ovoid, MIS-Implants Inc., Shlomi, Israel). The dimensions of the riders are listed in table 1, and were obtained corresponding to the distance between the implants.

Both the superior and inferior clamping devices consist of two parts and have the shape of the letter „T" (fig.2). The vertical part is used for fixing each device in the Testing Machine and may not have a width exceeding 10mm. The horizontal parts are used for fixing the bar/rider connection system: the riders are placed in the upper (mobile) device and the bar in the lower (fixed) one. The lower horizontal metal part is a metal frame, whose role is holding the acrylic resin, where the assembly consisting of the analog implants and cast Dolder bar are embedded (fig.3).

The riders are positioned in the upper acrylic device only after the Dolder bar has been put in its final position in the lower device of the Testing Machine, to make sure that the riders do not drift away from the insertion axis.

The inferior clamping devices was tightened into the lower part of the Testing Machine and the superior clamping devices was fixed in the upper, mobile part. After it has been verified that during the insertion/withdrawal process the rider and the bar join/meet each other in the correct position, the Testing Machine was started, the number of cycles began to be numbered, and a series of measurements of the retentive force were done.

Fatigue test and tensile strength test

Fatigue test was performed using Fatigue testing machine, Walter-Bai, 10 kN. Specimens were submitted to 5000 cycles of insertion and removal of components along the path of insertion (*f=1 Hz*). Retention force values were calculated before the fatigue test and every 500 cycles of insertion and removal. The measurements were performed with Tensile testing machine, Zwick/Roell, 5 kN, with the speed 1mm/min. Maximum retention force values were an average of two measuremets taken at each interval. Tests were performed at room temperature and humidity, with peak load forces being measured in Newtons.

Based on the assumption that a patient removes his/her prosthesis three times a day, this test simulated with the 5000 cycles 5 years of manually insertion/desinsertion for cleaning. Also the studies of Gamborena&Fromentin showed that 5000 cycles of the fatigue test corresponds to 5 years of clinic usage, which is considered long enough for prosthesis replacement [15].

The evolution of the retention force was analyzed at the end of the wear test, for each of the 4 situations. The results

Table 1
THE DIMENSION OF THE RIDERS

	Number of riders. Sizes.					Number of bars. Sizes.				
Situation 1	L=12 mm					L=14 mm(between Mesial surf.cemented crowns), h=2,3mm				
Situation 2	L=11 mm					L=15 mm(between implant's screws) h=2,3mm				
Situation 3	Left		Center		Right	Left		Center		Right
	5 mm		5 mm		5 mm	L=9mm, h=2,3mm		L=9mm h=2,3mm		L=9mm h=2,3mm
Situation 4	Left extension	Left	Center	Right	Right extension	Left extension	Left	Center	Right	Right extension
	7mm	5mm	4mm	4mm	7mm	L=10mm h=2,3mm	L=9mm h=2,3mm	L=9mm h=2,3mm	L=9mm h=2,3mm	L=10mm h=2,3mm

	Distance between implant center			Size of implants
Situation 1 (2implanturi)	15 mm			L=10mm, Q=4,20mm
Situation 2 (2implanturi)	15 mm			
Situation 3 (4implanturi)	9 mm	9 mm	9 mm	
Situation 4 (4implanturi)	9 mm	9 mm	9mm	

Table 2

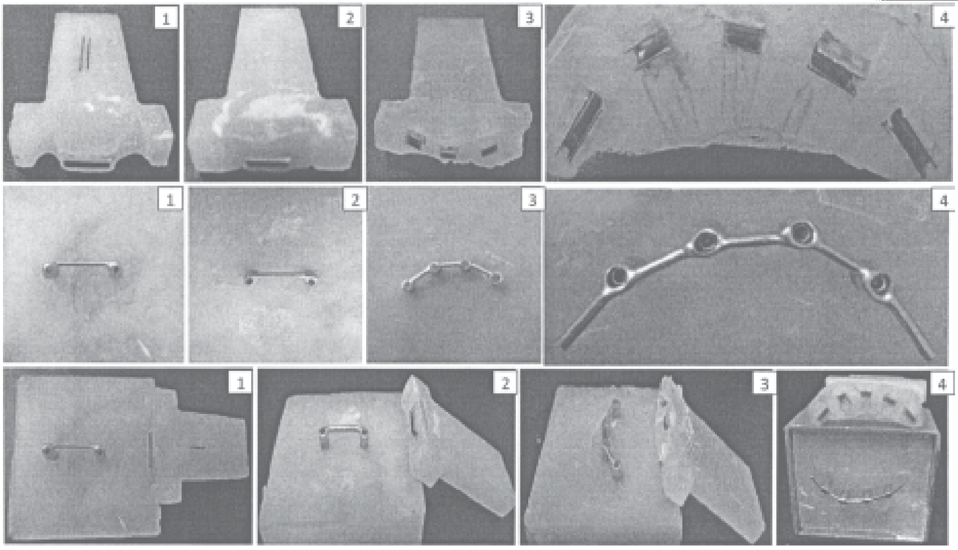


Fig. 3

Number of extractions	Maximum dislodging force (MDF)							
	Situation 1		Situation 2		Situation 3		Situation 4	
0	61.49	58.655	53.38	53.06	59.363	60.075	105.15	103.895
	55.82		52.74		60.787		102.64	
500	55.06	54.431	53.83	53.898 5	47.74	55.24	101.495	100.2325
	53.802		53.967		62.74		98.97	
1000	54.86	53.09	50.76	51.21	54.363	53.571 5	92.218	90.779
	51.32		51.66		52.78		89.34	
1500	49.78	50.305	49.46	48.822 5	51.7	52.11	98.35	94.855
	50.83		48.185		52.52		91.36	
2000	47.71	49.66	48.78	48.541	51.9	51.9	96.3	90.305
	51.61		48.302		51.9		84.31	
2500	47.08	48.28	49.48	49.841 5	50.59	48.315	96.23	94.22
	49.48		50.203		46.04		92.21	
3000	48.48	48.51	44.08	44.59	48.69	48.765	93.745	93.3975
	48.54		45.1		48.84		93.05	
3500	48.05	47.275	41.24	43.56	49.45	48.635	92.82	88.815
	46.5		45.88		47.82		84.81	
4000	48.09	47.885	48.96	47.15	48.72	47.755	72.76	68.845
	47.68		45.34		46.79		64.93	
4500	49.49	46.905	45.92	46.345	48.9	47.65	82.68	81.235
	44.32		46.77		46.4		79.79	
5000	46.73	45.395	44.86	44.505	47.5	47.14	77.32	73.29
	44.06		44.15		46.78		69.26	
Retention loss %		22.61%		16.14%		21.54%		29.45%

Table 3
FATIGUE TEST AND TENSILE STRENGTH TEST

were compared with each other, and compared with clinical observations and data published in the literature.

The retentive force was evaluated as the maximum force when the attachment components were separated. Maximum dislodging force (MDF) was recorded at the point where the rider has exceeded Dolder bar equator and after that the retention force began to decrease.

Results and discussions

Fatigue test and tensile strength test results are presented in table 3.

Initially, situation 4 showed the greatest tensile force, followed by situation 3, and for situations 1 and 2 were recorded similar values of tensile force (maximum dislodging force).

As a result of Fatigue test, the retention force demonstrated a decrease from the initial pull to the final pull test. The evolution of the retention force after simulation of wear is showed in figure 4.

At the conclusion of the study (5000 cycles), siuation 4 had significantly the highest retention force, followed by situation 3, and no significant differences were found between situation1 and 2. The order has been preserved as at the baseline, but the percentage of loss of retention was different at the end.

Lack of retention is the most frequent problem with existing conventional acrylic resin dentures. Easily dislodging of the prosthesis during speech or eating can put the patients in an embarrassing situation, thus they constantly living in fear of losing the denture. A retentive

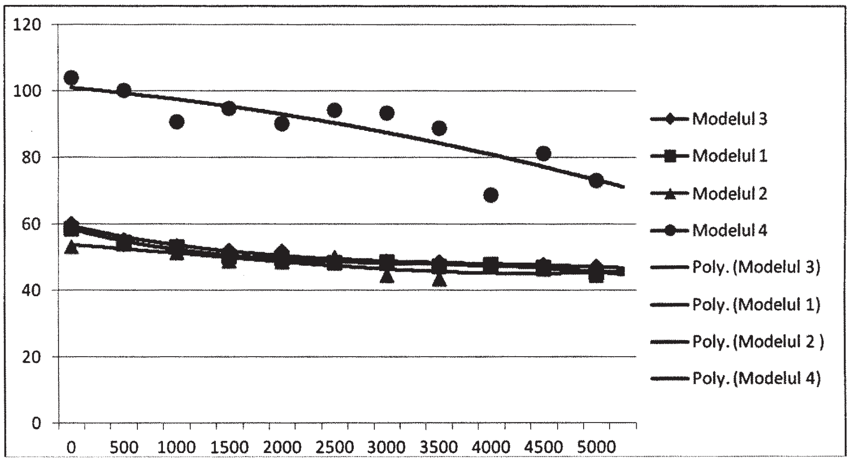


Fig. 4

denture contributes dramatically to patient acceptance of the definitive prosthesis [16].

Objectively, the prosthesis degree of retention and stability is influenced by the type, design, alignment, or position of the connection system. Subjectively, the degree of retention is clinically evaluated by the patient according to prosthesis behaviour during function and his/her ability to adequately place and remove it [17].

Despite the popularity of overdenture bar/rider systems, there are not many in vivo or in vitro published studies that test their retention strength or their behaviour over time.

It is very complicated to accomplish intraorally the measurements of retention and wear during the function. Clinical assessment of implant overdenture retention should take into consideration forces associated not only with the used attachment system but also with the amount and viscosity of saliva. Implant angulation, a not well-defined path of insertion of overdenture (when the insertion and removal is done by a machine, the path is always the same), minimal displacement of overdenture in three dimensions during function and parafunction and so on, are other important parameters that should not be neglected [13]. Trying to take into account all these factors may conclude in poor validity and reproducibility of results and may be associated with the wide variation of values reported in the literature [18].On the other hand, in vitro studies are usually easier to perform, without taking into consideration the oral environment and biomechanical factors. Perhaps for this reason data generated exclusively in laboratory tests may be of limited clinical relevance. Nevertheless, these measurements are used as parameters for assessment of denture retention [18].

The initial retention of a particular attachment system may indicate its clinical predictability and performance and influence patient acceptance of the prosthesis. Starting from these premises, in this study we tried to record the retention force initial values for the chosen siuations (1, 2, 3, 4), and to observe its evolution, after the wear test.

The results obtained in our study show that there are no significant differences between the siuations 1 and 2 in terms of retention force values, at the end of the fatigue test. In siuation 1, the clip is longer than in siuation 2, so contact area between the bar and the clip is bigger, resulting a greater amount of friction, which directly influences the retention force. These findings are consistent with Bottega's study results[15], which also show that the greater the friction, the greater the retention is, after the measurement of two different connection systems' retention force (O-Ring and Clip/Bar). For all the siuations that we have tested, we have used the same diameter of the rider/bar and also the same design configuration. Thus, the slightly increased retention force value in siuation 1 compared to siuation 2, is explained by a larger contact surface of a longer rider, which is a benefit and a useful information in selecting the proper size of the clip, when the used connection system is the bar with the rider.

Viewed from another perspective, the phenomenon occurring at the bar/rider interface is similar to what occurs at the interface between a prepared tooth and a cast crown: : the longer the lenght of the pillar, the bigger is the contact area and consequently the crown will be better retained on the abutment. Additionally, the sidewalls of the metal rider are almost parallel, so the taper is minimal, which positively influences the retention, as in the example with the casted crown, whose retention is even greater as the opposite walls of the prepared tooth have less taper and are almost parallel to each other. Using the same comparison Petropoulos V & al. [16] justify the differences between the registered retention forces when comparing Zest Anchor and Zest Anchor Advanced Generation (Escondido, CA) connection systems in his study conducted in 2011.

At the same time, the retention forces recorded at the end of the fatigue test forsituation 3 (with 3 riders) did not show big differences from the retention forces recorded for situations 1 and 2. This finding is surprising, given that the retention provided by each clip might be expected to be cumulative. The discrepancy in expected retention may be related to the distribution/position of the retentive clips on the bar. Our study highlights, in other experimental conditions (different situations , 1 and 3 riders, mandibular Overdentures), the same conclusion reached by Williams & al. [17]in their study in 2001, in which they recorded the retention force for bar/rider connection systems (2 and 4 riders, maxillary Overdentures) and demonstrated that the increasing of the number of the Hader clips, with different positions, didn't significantly increase the retention force.

Following the same reasoning which refers to the size of the contact area between the rider and the bar, we could explain why in our experimental study, in SITUATION 4 was recorded the highest resistance against vertical tensile forces. There are studies that point out that Overdenture's retentive force increases when increasing number of riders. Thus, Breeding & al., show higher retention force values for the acrylic resin overdentures with two riders than for the overdentures with one rider, for a single bar segment, in a vertical tensile test [19]. Following the measurements, our study also highlights that the highest retention strength was obtained for the situation with 5 riders, with significant and obvious differences from the rest of the Situations.

After the wear simulation, the retention in situation 1 decreased by 22.61%, in situation 2 decreased by 16.14%, in situation 3 decreased by 21.54%, and respectively in situation 4 decreased by 29.45% and was in line with the results of other studies, which investigated fatigue behavior. So, the retention force after the wear simulation of the acrylic rider overdentures with cast bar / prefabricated gold rider, did not decrease significantly.

Loss of retentive force over time is mainly attributed to wear of attachment components. According to our observations, wear can be caused by friction that occurs between the bar and the rider, a phenomenon that has also been mentioned by Breeding&al[19], Walton & Ruse [20]or Epstein & al [21]in previous studies.

Another phenomenon observed during this "*in vitro*" study was related to the elasticity of the golden rider, that begins to diminish/disappear after a few thousands of insertion/desinsertion cycles. According to Craig[22], a material that is momentarily submitted to stress below its yield strength returns to its original form without any internal or structural change. Still, if this stress is repetitive as in a fatigue process, the material can suffer definitive deformations. The strain energy absorbed during insertion was divided into elastic (recoverable) and plastic (permanent) components. If permanent deformation occurs, a rapid loss of retention is observed[23].

Deformation of the riders, especially of their distal edges (parallel arms begin to move away, becoming divergent), when using multiple riders and when their position is not straight (but on an arc of a circle) is another remark during this test. This could be another reason for the retention to decrease over time. Also Chung & al. associated high forces used to disengage the Hader Bar and the metallic rider (during insertion and desinsertion) with the increased deformation of the retentive elements [24].

Conclusions

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

- the retentive force of the bar/rider attachment system is influenced by the number and the lenght of the riders;
- the fatigue test simulating 5 years of insertion and removal of the acrylic resin overdenture did not record a large decrease of retention values;
- based on the results of this research, the dentist can choose an appropriate bar/rider attachment system when using implant overdentures, according to the clinical situation. It is recommended to use five riders together with a long bar when a high amount of retention and resistance against lateral forces is necessary. For example, for a patient who has severe residual ridge resorption or used to remove and insert the denture frequently. One rider between two implants connected with a bar should be the choice when the denture-bearing capacity of the soft and hard tissue is high and the demand for overdenture retention is low. It is also suggested for the patients with dexterity problems, or poor hand manipulation.

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