In dentistry there was always a desire for imitation of the lost anatomical parts and their functionality. The more advanced is the damage of the stomatognathic system with no possibility of implant-prosthetic rehabilitation, the more we need to focus our attention towards a functional prosthetic removable resolution. There has always been a tendency to achieve perfection or optimum in the dental practice [1-4]. Initially this tendency was linked only to observation and correction of circumstances, but nowadays multiple software have been introduced, being capable to analyze the optimization possibilities on specific domains.

The first ones who created a calculus formulae to define the mathematical optimum were Fermat and Lagrange, and the term “linear programming” of George B. Dantzig’s and further Leonid Kantorovich’s studies in 1939, managed to define the term optimization (Wikipedia).

Since 1960 there have been multiplied, each one at a time, various mathematical theories defining (on computer) the optimization of different industry branches. Due to the applied mathematics generalization, in the dentistry domain are also known a number of projects and optimizations achievable by engineering methods that solve technology problems, design and partially those of technical execution. The optimization problems in our dental activity domain are especially focused on the functionality maximization of dental prostheses and on choosing the optimal theoretical and practical solutions to the biomechanics and mechanics problems of fractures [5].

The optimization problem of some prosthetic components is extremely complex [6-9]. It must be taken into account the anatomical parts that are replaced, their different consistency, composition and functioning mode in the whole body. Therefore the problems are always multi-objective (according to Pareto set) and the resolutions often multiple (Wikipedia). Thus the insertion of data into computer (which means under the imposed conditions) is essential to reduce errors in our results. The imposed conditions will be focused on the properties of the analyzed materials, on the support and pressure areas exerted by the prosthesis on the prosthetic field structures, also on the determination of critical areas. For optimal results a sufficient number of conditions is required (as in Hessian matrix) and constrictions (Wikipedia). By optimization, there can be solved feasibility dentures problems, can be achieved an optimal multidisciplinary design, as well as stochastic programming and optimizations, that are related to research.

Experimental part
Materials and methods
There have been studied 50 metallic frameworks of removable partial dentures, performed at the Dental Technology Specialization conducted in Timisoara and Craiova, on which there were analyzed the retention quality and clasps distortion by empirical methods. In the context of mathematical methods of the clasps profile optimization, we used the finite element method - “reverse engineering”, by which there were also analyzed 5 virtual models of cast clasps layout in order to improve their design and mechanical qualities (fig. 1). The models are made using a modern light curing technology of polymers type Liwa Dip Set, which allows the layout detachment off the model (which was not possible in the conventional technology). The light curing modeling material is strong, has wax-like consistency, a very low contraction values and high flexibility.

The scanning was performed with a 3D laser scanner - model LPX-1200. The scanning had a scan step of 0.1 mm. The scanned surfaces were imported in the Pixform Pro software, which combined the surfaces and repaired them
so that they have continuity and perfect closure (fig. 2).

Tracking and marking the defects to repair them (signalized by PICZA program).

These areas that surround the external surface of the prosthesis like an eggshell were initially exported in graphics exchange specification (IGES) and then imported into the Solid Works 2007 to be converted into a solid model.

FEM analysis with software package, ABAQUS v 6.9.3 allows simulation of various situations that we found in our current practice.

Clasps profile optimization is determined by assessing areas of minimal resistance of the clasps components in order to achieve long lasting and retentive prostheses.

Results and discussions

From analyzing the dental clasps retention of the 50 removable partial dentures, the following data resulted as the two graphs below present. It follows that the percentage of optimal solving was higher than 50% and that the insufficient retention was caused either by negligence in processing/surface finishing and clasps adaptation or by their fracture. A significant percentage was that of the clasps deformation, which can be considered as excessive retention too, and also into the wicker retention, thus causing actual optimization problems.

Excessive retention was caused by: proximal dental interferences, excessive friction between the active arm of the clasp and the abutment tooth, the placement of the clasp edge in an area too retentive, the increased stiffness of the clasp arm due to excessive thickness, deformation of the clasp arm.

Excessive retention can lead to pole tooth fracture off the model in an attempt to force the prosthesis insertion, which cause (further) false assessments of the clasp retention force. Out of the optimization techniques chosen for cast clasps on which the excessive retention was observed, we opted for: marking the retentive area and polishing the clasp internal surface with sand rubbers, thinning the active arm of the clasp that has lost its elasticity, removing the evident roughness from the internal face of the clasp by polishing with sand rubbers (fig. 3).

They solve the problem completely. After the partial removal of interference areas, when the prosthesis is inserted in the oral cavity, it has to meet only a slight resistance while crossing the prosthetic equator.

The inefficient retention is more frequent than the excessive retention and correction is an improvisation without lasting perspective. This occurs when the active clasp terminal is located in an area with poor retention, when there was made an excessive processing/surface polishing or when the clasp distorted (deflected). The correction addresses especially to the acrylic component of the prosthesis as a partial lining that accesses the retentive subequatorial areas – areas of interference. The clasp repositioning by deflecting it with the pliers can lead to failure, because the deformation is not controlled and the clasp can break. To solve the ineffective retention, we recommend the use of adhesives for the third generation of teeth.

Clasps deformations lead either to sequential excessive retention or to a lack of retention, and they are always incorrectly resolved. They occur most frequently in profiles that have a more complicated aspect (eg. the COC clasp), at the preparation level for occlusal spurs, at the main connectors level of type dento-mucosal plate, which meet the role of opposing arms, too.

Applying the finite elements method to evaluate the metallic framework of RPD components, there were obtained virtual models on which we could test the states of stress and total deformation, following the application of similar occlusal biting pressure. Therefore, we could detect the minimal resistance areas, places where the clasp will break in the future. It was ascertained that the optimizations are only for circumstances, similar to those achieved by empirical methods, because the clasp is already casted, so there are just a few possibilities of summary corrections that can be done.

For this reason, using pattern made of light-curing polymers, which can be detached from the models, is the
future solution. The layout can be improved, rescanned 3D and reevaluated before casting the metallic framework of RPD, thus achieving a truly optimization of the clasps. Mimicking the masticatory process in the finite element analysis has analogies with current practice, with the RPD biomechanics, and allows performing some components of prostheses according to the actual requirements. The support areas were marked on prostheses and the application areas of forces per area units, in different variants: without support on alveolar ridge fibromucosa, with full or partial support (fig. 4).

We have also analyzed the support possibilities of the dental clasps at the terminus position of the prostheses (when the passivity functions of the clasp and prosthesis have been achieved) and in its dynamics during the going-down movement of distal extremity (free). In the passive area of prosthesis, the support is extended on all rigid areas of the clasp, while during the application of intrusive forces on the distal extremity of prosthesis, it is prone to oppose to the detachment and then the prop is stuck only at the tip of the retentive arm, partial and opposing in the occlusal rest. On geometric models we accomplished the stress and tensions analysis that occurred in different areas of the prostheses (fig. 5).

The performed study shows that: the lack of mucosal support generates strong breaking forces even of the main connector (3 mm thick) and of the secondary connector that connects clasp to the main connector. They can cause
permanent damage of the prosthesis by fracture in the above mentioned areas. Thus, it can be demonstrated objectively that the mucosal support is compulsory and necessary for the dynamic stability of prosthesis. For these reasons, we emphasize that is absolutely necessary to check the patients periodically and repeated coating of the prosthetic saddles on time.

Also from this numerical analysis we can observe the moment when the active arms of the clasps are overburdened. The metallic component yields/breaks down at the top of the active arms when the support on fibromucosa is partial and the masticatory forces that lower the prosthesis are applied distally – towards the free end of metallic framework.

If the adjustment of an excessive retention is related to insufficient processing of the maintaining, supporting and stabilizing means, the too small retentions are actually the failure of prosthesis construction, being the consequence of tempestuous processing, without discernment, without common sense [10 - 12]. Rather than a precarious retention, it is preferable a higher degree retention to normalize the situation. Setting the etiology confers specific features to the applied methods. However, in all cases, the etiology detection is necessary to accumulate experience, so that during the prosthesis reconstruction, these mistakes should not be repeated. An inadequate adjustment of the clasp, casted to increase or decrease retention, may emphasize the prosthesis instability, it can cause impairment (damage) to the surrounding tissues or even damage or fracture the retentive arms of the clasps. That is why all operations are executed repeatedly with patience and finesse.

The necessity to adjust the clasps retention of the partial metallic-frame dentures may occur either in the context of clinico-technical stages of performing the partial metallic-frame dentures, while checking the metal component, prosthesis insertion in the oral cavity, or after, or subsequently, at the old dentures misshapen by injury [1,13].

The situations in which we found an excessive retention are more frequent in technicians beginners, whereas those with lower retention or deformation to technicians, who have no patience during processing, are superficial, careless and do not work under the well-done-thing awareness. The doctor, who performs the finishing touches in cabinet, might make mistakes as well, transforming a
retentive prosthesis in one non-retentive. The clasps excessively retentive exert strong pressure on the pole teeth, and can be generators of their mobilization. It is practically the only situation in which the maintaining function of the clasps can be quickly and efficiently optimized [3, 4].

The reduced retention occurs in the finished prostheses of the investigated lot with a percentage of 22%. This is due to careless, tempestuous and empirical processing of the metallic and acrylic component, of the reduced working time, retention assessment deficiencies. If the distance clasp–tooth is little, the chance of correcting retention increases, but if the distance is longer than 0.2-0.3 mm, they break in 50% of cases. Of course this depends on the alloy properties, on the existing cast defects, on the applied forces during mastication and the type of clasp. Anyhow the span life and attrition resistance of a metallic structure is limited to 5 - 5.5 years [1].

The cast clasps deformations occur while a brutal unpacking, prosthesis slippage during processing especially the polishing process, caused by weak hand holding of the prosthetic piece and/or its drop. Besides, there might occur improper handling while inserting the prosthesis in the oral cavity, accidental droppings. The most common deficts (deformations) occur in the first period of use, when the patient was not accustomed yet with the insertion and pulling-out axis of the partial denture, then the defect can accidentally occur by dropping the prosthesis, of some accidents, assaults. They become clinically visible by the lack of adaptation and uniform contact of the clasps with the poles teeth or even the impossibility of a correct insertion till terminus position of prosthesis. Clasps deformations are coupled with excessive retention or lack of retention, therefore the attitude toward them is nuanced. Generally they can not be solved correctly, only partially.

More recently, the stress areas of the dental clasps can be evaluated on computer by the numerical simulation method with finite elements, which can give us factual data about where irreversible damages occur. Stress distribution shows up in some circular clasps (Akers clasp and posterior-action clasp) when pulling-out the prosthesis. Retention force was considered 5N. Cast clasps of removable partial metallic framework break, subject to time-varying loads, resulted especially after chewing, due to degradation by fatigue. The calculation result of the degradation factor by fatigue of a circular clasp shows that conventional fatigue resistance was 330 MPa, so it works experimentally about 5.5 years.

The advantages of the numerical analysis method with finite elements are related to: the possibility of handling some complex geometry, of solving some varieties of complex engineering problems from the materials resistance domain, solid mechanics, kinematics, electrostatics, aeronautics, etc. Material properties of the real structure are reproduced in full in its elements [7 - 9]. This specific feature of the finite elements has made this method to have a wide application, especially at structures made of composite materials.

The disadvantages are mainly related to the correctness of inserted parameters for the system probing, which, if not optimal, provide false or approximate solutions. The domain importance is marked by the over 400 books, and web pages. It should be noted that in context of the finite elements method, the approximation done is physical; a structural modified system substitutes a real continuous system. Mathematically there is done no approximation toward the real structure. By this, the finite elements method essentially differentiates from the finite differences method, where the equations of a physical system are solved by approximate methods. Using two-dimensional or three-dimensional elements makes the finite element method not to affect the structure continuity.

In dentistry the method became necessary because it is the basis of some more advanced analysis (at variable frictions), some more complex phenomena can be explained, which underlie the degradation of the metallic frame partial dentures. The main attachment elements of these prosthetic pieces, studied here, are the clasps (used in the technology of this prostheses type in 70% cases). The force retention and stress distribution in the clasps arms, represent the success key to the durability of the metallic frame partial dentures (without deformations or fractures).

First data about light-curing waxes used in the removable partial dentures technology were published nine – ten years ago [13 - 17]. Their using modifies the classic technology, reducing the working time and saving materials used in the intermediary stages. Anyway the technique is ingenious and perhaps it can be improved also through the profiles modify [3], that can improve the mechanical strength of the wax pattern and consequently of the metallic framework. Numerical simulations with FEM allow optimizing the shape of the retentive arms of the cast clasps, so that they are sufficiently flexible and not to produce harmful effects on the pole teeth, but at the same time to be effective in maintaining the prosthesis and its long lasting. This study revealed the possibility of some changes in size, location and the application mode of the external forces on one hand and, on the other hand, the type of hooks involved in the study.

Conclusions

The cast clasps optimization can be done empirically or by computerized mathematical methods.

- the adjustment of improper retention of the cast clasps must be done considering the etiology;
- the element analysis method has multiple applications. It allows the prediction of the optimal usage duration of certain partial denture parts and will allow the ruling out of human computing errors.
- the non-invasive experiments performed on polymeric layouts by the finite element method allow the clasps optimization, they being very promising, because the testing which can be performed are very close to reality.

References


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