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ADVANTAGES AND DISADVANTAGES OF IMPROVISED NYLON POLYAMIDES USED AS DENTURE BASE MATERIALS FOR FLEXIBLE PROSTHESIS - LITERATURE REVIEW

ПРЕДНОСТИ И НЕДОСТАТОЦИ НА ИМПРОВИЗИРАНИТЕ НАЈЛОНСКИ ПОЛИАМИДИ КОИ СЕ КОРИСТАТ ЗА ИЗРАБОТКА НА ФЛЕКСИБИЛНИ ПРОТЕЗИ - РЕВИЈАЛЕН ТРУД

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Abstract

This paper is a review of studies on flexible dentures and analysis of the results obtained after testing the properties of modified thermoplastic polymers (polyamides)used for producing partial dentures. In the past, the use of flexible dentures was limited due to their inconsistency. Over time and after numerous studies, manufacturers have been able to improve the properties of thermoplastic resins,thereby their use in dentistry has increased. The analysis and comparison of scientific papers published on PubMed in the last 20 years show that the flexibility and low degree of elasticity of these materials contribute to the comfort and longevity of the prosthesis. The problem of high water sorption was overcome by changing the chemical composition of the polyamide, whereas improving the polishing technique resulted in achieving an acceptable smoothness of the surface, which in turn reduced bacterial colonization. During the color stability tests, a color change was observed after immersion of thermoplastic resin samples in coloring liquids consumed in the daily diet. **Key words:** flexible dentures, polyamide, thermoplastic dentures, nylon.

Апстракт

Овој труд претставува преглед на студии за флексибилни протези и анализа на резултатите од испитувањата на својствата на модифицираните термопластични полимери (полиамиди) користени за изработка на парцијални протези. Во минатото, употребата на флексибилните протези била ограничена поради нивната непостојаност. Со тек на време и по бројни истражувања, произведувачите успеале да ги подобрат својствата на термопластичните смоли така што нивната употреба во стоматологијата се зголеми. Анализата и споредбата на научни трудови издадени на PubMed во последните 20 години покажуваат дека флексибилноста и нискиот степен на еластичност на овие материјали придонесуваат за удобност и долготрајност на формата на протезите. Со промена на хемискиот состав на полиамидот се надминал проблемот со висока сорпција на вода, а усовршувањето на техниката на полирање овозможила постигнување на прифатлива мазност на површината, со што пак се намалува бактериската колонизација. При испитување на стабилноста на бојата констатирана е промена на бојата по потопување на примероци од термопластични смоли во пребојувачки течности кои се конзумираат во секојдневната исхрана. **Клучни зборови:** флексибилни протези, полиамид, термопластични протези, најлон.

Introduction

Removable partial dentures are a common treatment choice for partial edentulism in everyday dental practice. Despite the great progress in the field of Implantology, many patients still use removable dentures to compensate for their missing teeth, instead of deciding for bridges over dental implants. The advantages of these prostheses over the fixed partial dentures are lower cost, easier maintenance in aspect of hygiene, overcoming the biomechanical as well as pragmatic issues associated with dental implants and avoiding possible implant failure[1].

The two standard types of removable partial dentures are **all acrylic resin prosthesis** (also known as acrylic flippers) and **cast partial dentures** (partial dentures comprised of a cast metal framework and acrylic resin prosthetic teeth). These two types of prostheses retain on the patient's remaining teeth using metal clasps. However, the visibility of metal clasps affects the aes-

thetic. Edentulous treatment implies rehabilitating both function and aesthetic, therefore, contemporary dentistry offers a third, aesthetically superior denture – the **flexible partial denture**. Flexible partial dentures are much more cosmetically pleasing, since they are comprised of direct retainers fabricated in a colored material instead of metal clasps. They fit more comfortably because they are made of thermoplastic materials, such as nylon, that are more flexible than the acrylic resin and chrome cobalt alloy, typically used in producing traditional dentures. Also, they are a suitable substitute for traditional dentures for patients who suffer from resin monomer and metal allergy. Flexible dentures are known to have better retention than acrylic prosthesis because of their improved adaptation to the tissue and the ability to utilize existing undercuts[2,3].

The most suitable and commonly used material for fabrication of flexible removable partial dentures is Valplast (Valpalst Int. Corp. USA). Other flexible materials available are Flexiplast(Bredent Germany), Lucitone FRS (Densply International Inc. Germany), Flexite, Flexite plus, Flexite M.P. (Flexite Company USA), Sun flex, Pro flex[4].

The aim of this study is to review literature regarding the mechanical, physical and clinical characteristics of improvised nylon polyamides used as denture base materials, with special reference to the reported disadvantages such as water sorption, warpage, surface roughness, bacterial contamination, difficulty in polishing and color deterioration.

Materials and methods

For the realization of this paper, a review of the available online literature on flexible dentures was made. Problems in clinical use that have arisen in the past were identified. Amore detailed analysis of the achievements and improvements of the flexible materials was made byresearching the electronic database of PubMed for studies published in the last 20 years, from 2001 to 2021, using the key words: flexible dentures, polyamide, thermoplastic denture, nylon.

Discussion

Polymethyl methacrylate (PMMA) is the most commonly used denture base material. Its usefor denture base fabrication dates back to 1937[5]. The materialremained popularto this day because of its numerous advantages including excellent aesthetic characteristic, low water sorption and solubility, adequate strength, low toxicity, easy repairand a simple molding processing technique. However, PMMA is not an ideal material due to discrepancies in its physical and mechanical characteristics. Problems like polymerization shrinkage, weak flexural strength, lower impact strength, and low fatigue resistance can often lead to denture failure (fracture) when chewing or when falling out of the patient's hand. Various efforts have been madein order to enhance some properties of PMMA, including addition of metal wires or plates, fibers, metal inserts and modification of chemical structure. In recent years, nylon polymer has attracted attention as a denture base material[6].

Nylon is a generic name for certain types of thermoplastic polymers belonging to the class known as polyamides. Nylon polyamides were first introduced in the construction of denture bases in the 1950s. The early forms of nylon polyamides were not as developed, thus the early flexible prosthesis had certain disadvantages. When compared to polymethylmethacrylate, nylon materials were rugged, less rigid, highly resilient, resistant to abrasion and practically unbreakable. Also they were very prone to discoloration and staining. On that account, their use was restricted to limited clinical cases such as repeated denture fractures, proven allergy to polymethylmethacrylate, lack of neuromuscular coordination and construction of orthodontic appliances. However, over time, nylon materials have been modified to gain dimensional stability, lower water sorption, better strength, thereby increasing their usage as a dental base material. With the progress in technology and understanding of material, these materials have surpassed their limitations and are finding novel applications in the fabrication of removable partial dentures, small to medium sized complete dentures, occlusal splints etc[7].

Flexibility

Because of its excellent balance of strength, ductility and heat resistance, nylon is the most suitable material available for flexible removable partial dentures[8].

Soygun and al. investigated the mechanical and thermal characteristics of Valplast (the most commonly used thermoplastic nylon) versus reinforced PMMA denture base materials. They came to the results that Valplast has higher transverse strength (117.22 ± 37.80 MPa) as well as impact strength (0.76 ± 0.03 kN) when compared to PMMA (transverse strength: 92.00 ± 11.13 MPa; impact strength: 0.44 ± 0.15). Also, the modulus of elasticity of Valplast was found to be lower than those of PMMA sample groups[9].

Polyamide materials have significantly lower flexural modulus than the PMMA polymers[10]. The flexibility of these materials prevents prosthesis from getting fractured and makes them more comfortable for the patient as they are lightweight[11].

Gokay and al. used a conventional heat-polymerized resin, QC-20 (Dentsply International Inc., Chicago, Il., USA), and a high-impact polyamide resin, Deflex (Nuxen SRL, Buenos Aires, Argentina), for testing the transverse strength and internal adaptation. Polyamide samples were more flexible PMMA and did not break during flexural strength tests.Polyamide test samples showed the significantly lower elastic modulus mean values (3705.93 MPa) contrasted with PMMA test samples values (6821.97 MPa). In contrast, the lower deflection mean values were evaluated from the PMMA samples[12].

Wieckiewicz and al. tested the elasticity of Polyamide-12 after artificial aging. For that matter, Polyamide-12 specimens were tested firstly dry, as obtained from the dental laboratory and then after 1000, 3000, and 7000 thermocycles. The results did not show any statistically significant differences (P >0.81) in the Elastic moduli as a consequence of the artificial aging thus proving the stability of the material[13].

Water sorption

The initial attempts to replace PMMA with polyamide as a base material did not achieve clinical success. Although it solved the problems of allergies and mechanical trauma, the early PA materials rapidly lost color, shape and stability due to continuous water uptake. Hence, contemporary dental laboratories developed improved PA materials that have a different chemical composition than the ones used in the 1950s, but the exact same chemical structure.

In order to measure water sorption and water solubility of the modern polyamide materials, Nguyen used two polyamide materials - Valplast and Breflex and compared them to PMMA. After several cycles of drying and immersing the specimens in water that ended with them being stored in a desiccator until the "reconditioned mass" was achieved, weight measuring showed that both Breflex and Valplast had a net increase in weight, which means they retain water. Although the obtained results were within the limits of the standard requirements,there was a notabledifference between the water sorption and solubility values of all three tested materials.Breflex had the highest water sorption that continued up to 8 weeks, while Valplast had the lowest. However, Valplast released a monomeric structure, contrary to Breflex that was chemically stable with no released compounds[14].

Similarly, Takabayashi concluded that different thermoplastic resins show different water sorption capacity. Only one of the polyamide resins -Lucitone had higher water sorption than the PMMA, whereas all the other resins (polyamide:Valplast and Flexite®supreme; polycarbonate: Reigning and Jet Carbo Resin; polyethylene terephthalate Estheshot) showed lower water sorption than PMMA. Nonetheless, the water sorption values of all the tested materials met the ISO standard for denture base materials, indicating that thermoplastic resins are stable and hygienic materials[15].

When evaluating sorption and solubility of PMMA and flexible denture base resin, Shah and al. concludedthat the flexible resin Valplastabsorbs less water and is less soluble than PMMA[16].

Surface roughness and polishing

Polishing or achieving adequately smooth and glossy surface is an important part of denture fabrication because surface roughness promotes adhesion and colonization of denture plaque[17]. Namely, surface roughness is positively correlated with the rate of bacterial/fungal colonization of biomaterials, so if rough surfaces become exposed to the oral environment, they may be more susceptible to microorganism adhesion and biofilm formation and can lead to infections[18].

Abuzar et al. pointed out that it is difficult to provide a satisfactory polished surface of polyamide dentures because of the low melting point of the material. Additionally, polishing causes overheating of the polyamides' surface, exposure of their fibers and fraying at the margins, so using pumice solution during polishing procedure helps reduce the problem of overheating.

In their study, they investigated the surface roughness (Ra) and clinical acceptability of polyamide denture base material and PMMA before and after polishing (lathe with pumice followed by high shine buffs). The difference in the Ra values of the polished polyamide and PMMA surfaces was found to be significant. Polyamide specimens produced a rougher surface both before and after the polishing. When polished, they became more than 7 times smoother, whereas PMMA became more than 20 times smoother using the same polishing technique. Still, the measured surface roughness of polyamide met the accepted norm of 0.2 μm Ra. That is to say, polyamide produces a clinically acceptable smoothness after conventional polishing by lathe, therefore can be used as a denture material in the oral cavity[19].

El-Din and al. studied the effect of different polishing techniques on surface roughness of three types of denture base materials: heat cured PMMA, thermoplastic polyamide and thermoplastic acetal. Two polishing techniques were used, the first one was pre-polishing rubberizing with brown rubber disc (1500 rpm, for one minute), followed by wet rag wheel polishing, 1500 rpm, with a fine pumice, for two minutes; while the second technique was the same as the previous one but addi-

tionally followed by dry rag wheel polishing (1500 rpm) with Tripoli compound for two minutes.

The results and analysis showed that surface smoothness of all materials was improved after polishing with a PMMA as the highest affected material. PMMA polished with both techniques showed a significant difference compared to thermoplastic polyamide and thermoplastic acetal, but there was no significant difference between thermoplastic polyamide and thermoplastic acetal[20].

Bacterial colonization

The bacterial colonization and the tissue compatibility of the polished polyamide (Valplast) and PMMA resin were examined in a vivo performed study by Olms and al. The results showed that an average of 17.8 different bacterial species grew on the PMMA specimens (24 as the highest number of different bacterial species), and 17.3 on the polyamide specimens with a similar bacterial distribution. The micronuclei in the examined palatal mucosa cells, as a marker for genotoxic potential of dental materials, were not detected. This study indicates that the composition of the bacterial biofilm developed after four weeks is not influenced by the type of resin itself. The two materials showed no cytological changes on the oral mucosa. This investigation suggests that both, polyamide and PMMA are suitable for clinical use as a denture base material[21].

Freitas Fernandes and al. used Polymethyl methacrylate (PMMA) resin (Acron MC) and polyamide resin (Flexite M.P.) specimens when testing the efficacy of denture cleansers on Candida spp. biofilm. The highest Candida spp. biofilm growth was shown to occur on polyamide resin when compared with PMMA[22].

Color changes

Color stability is the crucial aesthetical concern regarding flexible dentures. Color and translucency should be maintained during processing and resins should not get stained or change color during their clinical use. Intrinsic and extrinsic factors, or a combination of both, may affect color performances of the denture's material. Intrinsic factors include: degree of conversion, presence of residual monomer, as well as porosity due to inappropriate processing, pressure variation or overheating. The extrinsic stain is time-dependent and associated with eating habits, such as consumption of tea, red wine, cola and coffee, which cause color alteration due to the material's absorption and adsorption of these staining liquids. Discolored prostheses can lead to an unfavorable appearance and patient dissatisfaction. In addition, the absorption and adhesion of the colorants deteriorate the quality of the material by causing surface roughness, accumulation of debris, and colonization of infection-causing organisms like Candida albicans, which in turn can lead to damage to the underlying soft and hard tissues[23].

Sagsoz and al. examined the color changes of polyamide (thermo-injectable resin Deflex®) and polymethyl methacrylate, after storing them in tea, coffee, distilled water or denture cleaner. The color of the materials was evaluated at the baseline and after 7 and 30 days of storage in each of these solutions. Results showed that PMMA denture base resin has greater color stability than polyamide denture base resin. The lowest color change was observedin cases of PMMA stored in denture cleanser, while the highest color change was observed when the polyamide denture material was stored in coffee[24].

Contrary, Banu and al. concluded that thermoplastic resin is the least staining denture base material when compared to conventional PMMA and high-impact PMMA. This conclusion was reached when samples of the three materials were divided into two groups; one group was immersed in coffee, the other in cola, and change was noted after 12 and 24 hours. Afterwards, the samples were cleansed using a denture cleanser and analyzed again, but no significant difference in cleanability was observed[25].

Takabayashi used three types of commercially available thermoplastic resins in his study:

- Polyamide (PA-type) resins [Valplast (VAL), Lucitone® FRSTM (LTF) and Flexite®supreme (FLS)],
- Polycarbonate (PC-type) resins [Reigning (RP) and Jet Carbo Resin (JCR)], and
- Polyethylene terephthalate (PET-type) resin [Estheshot(EST)].

As a control group, he prepared polymethyl methacrylate (PMMA) [Acron (AC)] specimens.

All the tested materials were in the shade of "pink", as to resemble the typical denture base color.

The specimens were soaked in a coffee solution at 70°C and in curry for 60 hours. The spectrophotometric color measurements before and after soaking showed that the color stability of PC was the same as that of acrylic resin. However, PA and PET exhibited staining after soaking, particularly in the curry solution, suggesting that the color stability needs to be improved in these materials[26].

Sepúlveda-Navarro and al. tested the color stability of two heat-cured denture base acrylic (Lucitone 550, VipiCril) and one nylon denture base resin (Transflex) after immersion in beverages. The beverages used in this study were coffee, cola, red wine and distilled water. After 15 and 30-day periods of immersion, authors noted chromatic changes exhibited by specimens immersed in red wine, coffee and cola, pointing to red wine as the bever-

agethat causes the most significant staining of all resins[27].

Goiato and al. evaluated the chromatic alterations of flexible resinsPpflex and Valplast in comparison to the conventional resin Triplex when submitted to accelerated aging.Valplast presented the greatest chromatic alteration after accelerated aging[28].

Conclusion

The commitment to improve thethermoplastic denture base materials as well as the manufacturing techniques, contributed to successfully overcoming the disadvantagesof flexible partial dentures. Excellent balance of strength and low module of elasticity make nylon polyamide dentures comfortable and long-lasting. The measured values of water sorption and surface roughness of thermoplastic resins meet the accepted standards for denture base materials. Color stability is still a point of issue, thus more studies and modifications are necessary in order to achieve sublime aesthetics.

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