Prosthetic Dental Medicine

Mechanical Properties of Nylon Denture Base Materials: A Literature Review

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Механични Свойства на Найлоновите Протезни Материали: Литературен обзор

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Abstract

A wide range of thermoplastic materials for the fabrication of removable partial dentures (RPDs) is available for use in the everyday dental practice. The success of the prosthetic treatment depends on the properties of the selected denture base material. Thermoplastic polyamides, also known as nylons, are one of the four major groups of flexible materials used for treating partially edentulous patients with removable partial dentures.

The aim of the current review was to evaluate and compare the advantages and disadvantages between the different types of thermoplastic materials available and conventional polymethyl-methacrylate (PMMA) dentures in regards to their mechanical properties. A literature review was conducted using PubMed, Web of Science, Google Scholar, MDPI Open Access Journals and Wiley Online Library. There was no restriction on the date of publishing and language of publications. The keywords used for conducting the search were combinations of the following: "nylon dentures", "flexible dentures", "polyamide", "mechanical properties" and "PMMA".

Currently flexible polyamide is considered an alternative to the conventional acrylic resins due to its aesthetic and functional characteristics and physicochemical qualities. These materials can be used in denture fabrication in some cases such as severe undercuts, repeated fracture of conventional PMMA dentures, in aesthetic-concerned patients, those who have allergy to other denture base materials, and in patients where a thinner, more easily adaptable denture base material has to be used.

Although polyamides offer some clear advantages over the conventional PMMA resins, the question about their longevity and overall mechanical properties remains a topic of discussion.

Keywords: *polyamide, denture base material, mechanical properties, PMMA*

Резюме

Съществуват голямо разнообразие термопластични материали за изработката на снемаеми частични протези използвани в ежедневната дентална практика. Успехът на протетичното лечение зависи от свойствата на избрания материал за изработка на протезата. Термопластичните полиамиди, известни още като найлони, са една от четирите основни групи гъвкави материали, използвани за лечение на частично обеззъбени пациенти със снемаеми частични протези.

Целта на настоящия обзор беше да се оценят и сравнят предимствата и недостатъците на различните видове термопластични материали в сравнение с конвенционалните полиметилметакрилатни

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(ПММА) протези по отношение на техните механични свойства. Литературният обзор беше проведен чрез използване на PubMed, Web of Science, Google Scholar, MDPI Open Access Journals, Wiley Online Library и други, обхващайки научни публикации до ноември 2024 г. Нямаше ограничения относно датата и езика на публикациите. Ключовите думи, използвани за търсенето, включваха комбинации от следните термини: „найлонови протези“, „гъвкави протези“, „полиамид“, „механични свойства“ и „ПММА“.

Според резултатите от проучванията, понастоящем термоинжекционните гъвкави полиамиди се считат за алтернатива на конвенционалните акрилни смоли поради своите естетически и функционални характеристики, както и физико-химичните си качества. Тези материали могат да бъдат препоръчани за изработка на протези в случаи като тежки подрези, многократни фрактури на конвенционални ПММА протези, пациенти с естетически изисквания, алергия към други материали за протези и когато е необходимо използването на по-тънък и лесно адаптивен материал за изработка на снемаемата конструкция.Въпреки че полиамидите предлагат ясни предимства пред конвенционалните ПММА смоли, въпросът за тяхната дълготрайност и цялостни механични свойства остава обект на изследвания.

Ключови думи: *полиамид, гъвкави протези, механични свойства, ПММА*

Introduction

In modern dentistry, there is a growing trend among professionals to focus prosthetic treatment plans primarily on osseo-integrated implants, often overlooking the role of removable dentures in rehabilitation. However, removable partial dentures remain a practical and conservative option for restorative care, offering patients both functional and aesthetic satisfaction. The preparation for RPDs is minimally invasive, and the clinical procedure requires less time compared to implant-based treatments. Additionally, RPDs help restore lost supporting tissues, enhancing lip and facial structure, all without the need for surgical procedures [1, 2].

Although removable partial dentures present numerous benefits and are widely indicated, insufficient understanding of biomechanical principles and inadequate planning by professionals, as well as poor communication between practitioners and dental technicians often compromise their effectiveness. Additionally, the visibility of metal clasps when smiling and the use of acrylic resin can lower patient satisfaction with these dentures [3, 4]. Another common concern affecting patient acceptance of RPDs is the discomfort caused by the contact of the acrylic base and metal framework with the supporting tissues [5].

To address the drawbacks of conventional removable partial dentures, nylon-type polyamide resin was introduced in the 20th century to manufacture flexible removable dentures. These flexible dentures are entirely metal-free; however, they fully rely on the soft tissues for support. This reliance can lead to tissue injury if the alveolar bone becomes overloaded. To avoid this, a more recent approach combines a metal framework with anterior clasps and a thermoplastic denture base, offering improved rigidity and vertical support for RPDs [6, 7].

Given the variation in materials used in thermoplastic-based dentures, the term “nonmetal clasp denture” (NMCD) has been adopted as a more accurate descriptor [8]. NMCDs provide better aesthetics, as their clasps match the prosthetic base, enhancing patient acceptance.

The limited research consists mainly of clinical case reports without extended evaluations or in vitro studies focusing on specific material properties, leading to no clear consensus on their overall applicability. For these reasons, careful consideration is necessary when recommending NMCDs [9].

The current review focuses on the mechanical properties of the thermoplastic polyamides used in the fabrication of removable partial dentures, and more specifically on the hardness, flexural strength and surface roughness of the denture base material. These properties are critical for the success and longevity of the prosthesis [10].

Hardness

Hardness is the resistance of a material to penetration by another, harder body and is determined by measuring the constant depth of penetration using various testing methods. The most commonly used method is the Vickers test, performed with a hardness tester [11]. The wear resistance of the material depends on its hardness.

In 2012, Ucar et al. [12] compared the hardness of a polyamide-based denture material (Deflex) with that of a conventional PMMA plastic used for injection-molding and a conventional PMMA formed by compression molding. They found that Deflex exhibited lower hardness compared to the other two materials. In a study by Shah et al. [13] PMMA showed higher hardness values than the flexible plastic under investigation. This result may be attributed to the high monomer-to-polymer ratio, the material's composition, and the presence of methyl methacrylate monomer. Additionally, cross-linking agents may also be present in the material. The flexible resin demonstrated lower hardness values and contained fewer cross-linking agents, indicating that cross-linking agents could influence surface hardness.

In 2020, Fitri et al. [14] compare the hardness of conventional PMMA resin used for fabrication of removable prosthesis with thermoplastic polyamide base material and concluded that PMMA demonstrated higher hardness overall. In the same year Shatta. et al. [15] came to the same conclusion.

Samarla et al. in 2021, after comparing the surface hardness of conventional PMMA and a nylon based (Valplast) denture base material came to the conclusion that the conventional material exhibited higher levels of hardness [16].

The lower wear resistance of thermoplastic polyamides compared to conventional PMMA plastics is further confirmed by a study conducted by Hamanaka et al. [17].

From the available literature it can be concluded that that conventional PMMA demonstrates higher hardness than the thermoplastic polyamide materials.

Flexural strength

Flexural strength measures the load required to deform and fracture materials under opposing, non-axial (bending) forces [18]. The most commonly used methods for assessing flexural strength are three-point and four-point bending tests. Generally, the more flexible a material is, the lower its flexural strength, and vice versa. Thermoplastic polyamides fall into the category of flexible plastics and are therefore expected to exhibit lower flexural strength.

Flexural strength is frequently evaluated to understand the mechanical properties of materials used in the fabrication of removable prosthesis [10, 19, 20].

Pfeiffer et al. conducted a study comparing the flexural strength of thermoplastic polyamides (Valplast, Lucitone FRS) with conventional PMMA and concluded that thermoplastic resins have lower flexural strength and elasticity modulus [21]. Numerous other researchers, who reported similarly low values when analysing the mechanical properties of thermoplastic polyamides [22–24] support these findings. In another study, Hamanaka et al. also reported relatively low flexural properties of thermoplastic resins within the proportional limit (σP) [25, 26]. However, some authors have observed higher flexural strength values for thermoplastic polyamides compared to conventional PMMA materials [24, 27, 28].

In a 2020 study, Nasution et al. compared the flexural strength of the thermoplastic polyamide "ThermoSens" by "Vertex Dental by 3D Systems" with "Bio-Tone" by "Denken-Highdental" and the thermoplastic resin "TCS" by "TCS Dental." They concluded that "ThermoSens" demonstrated a higher elasticity modulus and, consequently, greater flexural strength compared to the other thermoplastic resins [29]. Similarly, a 2016 study by El-Naihoum et al. compared the flexural strength of conventional PMMA with "ThermoSens" and found that the thermoplastic polyamide exhibited superior flexural strength [30].

The high flexural strength of the flexible denture base materials is also reported in a study carried out by Gökay et al. in 2021, where they compared it with conventional PMMA using a three-point bending test [31].

It is reported that the modification or reinforcing of nylon denture base materials using different types of fibers does not lead to a loss of flexural strength [32, 33].

Some authors report controversial findings regarding the flexural strength of nylon denture base materials when compared to that of conventional PMMA base materials [34].

There is no consensus among researchers regarding the reported mechanical properties of thermoplastic materials, either within the scientific literature or between literature data and manufacturers' specifications [35].

The lack of findings in the present literature highlights the need for further investigations into the flexural properties of thermoplastic polymers used in dentures bases, utilizing standardized testing methods to ensure reliability and comparability.

Surface roughness

The main disadvantage of the thermoplastic polyamide is defined by the surface characteristics of the material and consists in the ability of their surface to be more easily scratched and damaged which also contributes to their matting and discoloration [35].

Surface roughness is a result of the manufacturing process used to create the material or structure. The average surface roughness (Ra), also known as the arithmetic average (AA), is measured as the mean deviation of surface peaks and valleys, expressed in microinches or micrometres. ISO standards refer to this parameter as CLA (Centre Line Average), and the two terms are considered synonymous [37].

In a study from 2024, Chuchulska et al. came to the conclusion that higher flask and plaster temperatures slow down polymer solidification, resulting in larger macromolecule formation, which enhances mechanical properties and surface features [38].

The International Organization for Standardization (ISO) sets a clinically acceptable surface roughness standard of up to 0.2 μm. A rougher surface can cause patient discomfort, affect the prosthesis's colour stability, and promote microbial colonization and biofilm formation.

Abuzar et al. [39] compared the surface roughness of polyamide-based dentures (Flexiplast) with conventional PMMA dentures (Vertex RS) and concluded that polyamide samples exhibited a rougher surface compared to PMMA, both before and after the polishing process used in the study.

The rougher surface of dentures made from thermoplastic polyamides may also result from errors during the manufacturing process. Defects in flasks, as well as the higher temperatures and pressures required for their fabrication compared to PMMA, can contribute to surface imperfections in polyamide dentures [40].

Applying conventional polishing techniques to thermoplastic polyamides can achieve a smoothness comparable to that of PMMA samples (41), remaining within the clinically acceptable standard of 0.2 μm [41].

Similar results were observed in another study conducted by Kawara in 2014 [42], which evaluated the surface roughness of four thermoplastic materials (polyamide: Valplast, Lucitone FRS; polyethylene terephthalate: EstheShot; and polyester: EstheShot Bright) and two conventional denture materials (heat-polymerized: Urban; and autopolymerized: Pro-Cast DSP) using a scratch test. The findings indicated that the surfaces of thermoplastic denture materials are more easily damaged compared to those of conventional PMMA materials.

In a study carried out in 2021 by Polychronakis et al. [44] in which the surface roughness of conventional PMMA and nylon denture base material were compared after the removal of denture adhesive the results show that the nylon material demonstrated higher levels of roughness. The same conclusion can be drawn when comparing

the surface roughness after the use of toothbrush to clean the nylon denture [45].

Surface roughness values exceeding 0.2 μm can lead to increased plaque accumulation and microbial colonization on the denture surface [46,47]. Furthermore, Tripathi et al. [48]. noted that most disinfectant solutions for removable dentures tend to increase surface roughness. Their study compared the effects of two denture cleaning agents, "Fittydent" and "Clinsodent," on the surface roughness of conventional acrylic and thermoplastic plastics. The surface roughness (Ra) of conventional acrylic samples increased from 0.22 μm at day 0 to 0.27–0.29 μm at 15 days, 0.29–0.31 μm at 30 days, and 0.30–0.31 μm at 45 days. In contrast, thermoplastic samples showed much higher initial and progressive roughness, starting at 1.31–1.27 μm at day 0 and rising to 1.46–1.66 μm at 15 days, 1.50–1.69 μm at 30 days, and 1.50–1.69 μm at 45 days. In a similar study carried out of Elsaiedy et al. in 2023, in which denture cleanser were used on polyamide denture base materials it was concluded that the cleaning agents had a negative effect on the surface roughness of the base material [49].

This raises questions about the suitability of using chemical cleaning agents for thermoplastic dentures. Dental professionals must be familiar with the composition and proper use of various cleaning agents and methods, as well as their effects on the surface, mechanical, and colour properties of dentures. Surface roughness plays a critical role in the durability and biological compatibility of denture prosthesis.

Conclusion

As a result of the conducted review it can be concluded that when it comes to the hardness of thermoplastic polyamide (nylon) denture bases materials there is a consensus that the majority of publications indicate that the flexible materials have lower hardness.

The majority of the authors in regards to the flexural strength of the thermoplastic polyamide materials when compared to conventional PMMA base materials report that the nylon dentures exhibit a lower modulus of elasticity and therefore higher flexural strength than the conventional PMMA.

The surface roughness of the nylon denture base materials is considered by the majority of the authors to be the biggest disadvantage of this type of materials. Both chemical and mechanical disinfection are reported to negatively affect the surface of the nylon dentures which can lead to reduced longevity of the prosthesis.

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