

# Polyamides in Dentistry

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## Abstract

Thermoplastic resins have been used in dentistry for over 50 years. Since that time their applications have continued to grow, and the interest in nylon based materials have increased. With the development of new properties, there are certain to be additional new applications for thermoplastic resins in the future, to help patients with damaged or missing teeth. The dentists have to meet growing demands for prosthetic rehabilitation due to population aging and higher requirements on the quality of life. Herein in this article we will be discussing in detail properties of nylon based materials and their various implications in dentistry.

**Keywords:** Nylon, Injection molded, Denture, Resin

## Introduction:

Thermoplastic resins have been used in dentistry for a very long period of time. These resins may be repeatedly softened by heating and hardened by cooling without undergoing a chemical change. They may be considered as being composed of bundles of chainlike molecules (called polymers) of many different lengths and molecular weights. They can be broadly classified as thermoplastic acetal, thermoplastic polycarbonates, thermoplastic acrylic and thermoplastic nylon.<sup>1</sup>

Thermoplastic acetal as a homo-polymer has good short term mechanical properties, but as a copolymer, acetal has better long-term stability. These resins resist occlusal wear and are well suited for maintaining vertical dimension during provisional restorative therapy. While stronger, acetal does not have the natural translucency and vitality of thermoplastic acrylic and polycarbonate, thus these materials might offer better results only for short term temporary restorations. Thermoplastic polycarbonates are a polymer chain of bisphenol-A

carbonate. Polycarbonates are ideally suited for provisional crowns and bridges but not suitable for partial denture frameworks.

Thermoplastic acrylic has been used in dentistry for many years in the form of temporary crowns and thermal polymerized as baseplate material for partial and complete dentures. Thermal polymerized PMMA demonstrates high porosity, high water absorption, volumetric changes and residual monomer. They have poor impact resistance, tensile and flexural strength for a variety of applications. Thus, improvised thermoplastic nylon can be a useful alternative to polymethylmethacrylate in special circumstances where higher flexibility, higher resistance to flexural fatigue, higher impact strength is required.<sup>2</sup>

Although clinician's skills and experience play a major role in designing and fabricating an optimum prosthodontic restoration, the selection of denture resins is equally important, especially when the patient has to use the prostheses for long period of time.<sup>3</sup> Nylon polyamides were first introduced in the construction of denture bases in 1950s.<sup>4</sup> Nylon is a generic name used for certain types of thermoplastic

polymers belonging to the class known as polyamides. Nylon polyamide was developed as a result of the classic research of W.H. Carothers and associates of the Du Pont Chemical Co. of America, carried out during the company's search for a synthetic fiber forming material (1928 – 1938).<sup>5</sup> These polyamides are produced by the condensation reactions between a diamine and a dibasic acid. The use of nylon as a denture base material has been described in the literatures in the 1950s.<sup>5-7</sup>

In 1950's as compared to polymethylmethacrylate, nylon material were rugged, less rigid, highly resilient, resistant to abrasion and practically unbreakable. However due to certain disadvantages of the early forms of nylon polyamides such as tendency of base color to deteriorate, stain, high water sorption, development of surface roughness after a few weeks' wear and difficulty in processing, its use was restricted to limited conditions such as repeated denture fractures, proven allergy to polymethylmethacrylate, lack of neuromuscular coordination and construction of orthodontic appliances.<sup>8-10</sup>

In order to overcome these shortcomings, Nylon with relatively low water sorption levels and melting points, were developed. It was further modified by reinforcement with glass fiber<sup>10</sup> and glass spheres<sup>5</sup> to increase its potential use as a denture base material. This improvised material showed better strength, stiffness, dimensional stability and lower water sorption. With the progress in technology and understanding of material, improvised nylon polyamides have surpassed its limitations and are finding novel applications in the fabrication of removable partial dentures, small to medium sized complete dentures, occlusal splints etc. Their usage as denture base material is still limited due to limited facilities and lack of knowledge of these materials. Herein in this article we will be discussing in detail the properties of nylon based materials and their various implications in dentistry.

## Properties

### Physical Properties of the Nylons

Nylon is a crystalline polymer whereas polymethyl methacrylate is amorphous. Thus in solid nylon there is more or less ordered parallel packing of the long chain molecule which is due to strong attractive forces between the chains. This crystallinity account for the nylon characteristics of lack of solubility in solvents, high heat resistance, and high strength coupled with ductility. The outstanding features of the nylons are their toughness, low density, abrasion resistance, higher melting point and resistance to chemical attack.

Since nylon is insoluble in almost all common solvents it cannot be dough moulded by usual dental techniques, but molten material must be injected into the flask under pressure. The high mould shrinkage is a serious issue. The flexibility coupled with its strength, enables it to resist all normal attempts to fracture. Previous workers have criticized the flexibility of nylon on the basis that this flexibility can lead to uneven loading of the supporting mucosa and bone particularly in the mandible.<sup>4,5,11</sup>

### Mechanical Properties of the Nylon

The chief advantage of nylon lies in exceptional mechanical properties of resistance to shock and repeated stressing, it has higher fatigue resistance compared to PMMA. Nylon has higher fatigue resistance than polymethyl methacrylate, although no comparative data under mouth conditions are yet available.<sup>5</sup> Though nylon has superior mechanical properties than any other non metallic base yet there are some serious limitations such as processing difficulties and dimensional changes.<sup>12,13</sup> The chief advantages of nylon denture bases are strength and lightness. The ultimate tensile strength of nylon AI00/M is **10,000-11,500**lb./sq. in. as compared with 7,000-8,000 lb./sq. in. for acrylic. This makes skeleton denture designs, which would be impracticable if made in acrylic, a feasible proposition when made with nylon. It has higher abrasion resistance, elastic memory, creep resistance and is conductive to cyclic stress.<sup>5,12</sup> These denture

base resins have lower flexural strength at the proportional limit, low elastic moduli along with good fracture resistance.<sup>14,15</sup>

### Dimensional Changes

Nylon is hygroscopic, its moisture content varies slowly with the surrounding conditions. On immersion in water the material swells, i.e. there is linear expansion.<sup>5</sup> Processing the denture base materials produced unequal deformation in different dimensions (anterior-posterior and cross-arch). The magnitude of this dimensional change depends on the conditions of moulding, shape of the mould, and direction in which it is measured.<sup>13</sup>

### Thermal Properties, Bacterial Growth, Staining

Nylon has low coefficient of linear expansion and galvanic conductance.<sup>5,12</sup> According to Abuzar et al polyamide denture base material when polished with conventional laboratory technique became more smoother than PMMA when using the same polishing technique. However the surface roughness of polyamide was well within the accepted norm and was clinically acceptably smooth after conventional polishing by lathe.<sup>16</sup> It seems likely that at least part of the surface roughness may be due to growth of bacterial plaques on the surface of the nylon. In few cases smear layer were made from surface scrapings of the nylon denture bases and of the acrylic teeth on the bases which resulted in clinically noticeable staining.<sup>4,6,10,17,18</sup>

The highest *Candida* species biofilm growth was shown to occur on polyamide resin when compared with PMMA.<sup>19</sup> Although flexible resins present advantages in terms of esthetics and comfort, studies assessing chromatic and micro hardness alterations of these materials are still scarce in the related literature.<sup>20</sup>

### Flexibility

Flexibility is a property, possessed by nylon, which is not usually considered to be advantageous in denture base materials. It can, however, prove to

be a useful property in certain types of partial dentures while being unsuitable for other types.

The flexibility of nylon varies greatly depending on the type of moulding powder used, temperature of injection, pressure of injection surplus nylon remaining in the cylinder after injection was found to be brittle. This was attributed to the fact that it had not been under pressure when it set. More recent grades of nylon with low water absorption have proved to be more flexible. It may be worth mentioning that full dentures made of nylon are not flexible since they are usually too thick to display this property.<sup>6</sup>

It was found that clasps made of nylon had to be rather bulky in order to function efficiently. Thin clasps which were adequate for retention when the denture was first fitted tended to warp away from the teeth after a few weeks wear. This was probably due to slow release of strains which had been induced during moulding. Owing to the flexibility of the base it was possible to utilize undercuts, for retention, which would normally have to be blocked out on an acrylic or metal base.<sup>6</sup>

Thermoplastic resins for non-metal clasp dentures exhibiting low water sorption and solubility offer hygienic advantages. Since they have a low modulus of elasticity and are easily manipulated, these materials make it possible for larger undercuts to be used for retention compared to acrylic resin.<sup>18</sup>

Flexibility can be advantageous in conditions when the buccal undercut on the maxillary tuberosity are present together with reduced width of the buccal vestibule.<sup>21</sup> Patient with systemic sclerosis and those who suffers from scarring in the oral and facial areas due to disease, trauma, or burning injuries, it is determined that long-term comfort and function could be achieved only through the use of a flexible removable partial denture.<sup>22</sup> Nylon is also an effective method for correcting gingival recession by fabricating a flexible gingival epithesis. However, discoloration of the epithesis still remains a problem.<sup>23</sup>

### Comparison between injection moulded and compression-moulded resins:

Nylon has unusual injection moulding characteristics since it melts sharply at a relatively high temperature to a mobile liquid in contrast to the more usual behavior of most other thermoplastics which display a gradual softening over a broad temperature range to a viscous fluid. Little increase in mobility of the melt is obtained by heating nylon above its melting point. For the same reason the material has been employed in the solid state, thus reducing the inclusion of air which occurs when granules are used. The mobility of molten nylon is the reason why heavy injection pressure is not necessary.<sup>5,6,13</sup> It is interesting to note that injection-molded resins were more resilient than their compression-molded counterparts. Injection-molded resins generally require a greater monomer content to improve flow characteristics and facilitate filling of the mold cavity. This often results in additional unreacted monomer within a polymerized resin. In turn, the unreacted monomer may serve as a plasticizer, thereby increasing the resiliency of the polymerized denture base resin. The increased amounts of unreacted monomer may account for at least part of the resiliency in the injection-molded resins. The completeness of polymerization is significant for 2 major reasons; firstly, the degree of polymerization affects the mechanical and geometric properties of resultant prostheses. Second, unreacted monomer may produce undesirable effects in the human body. Consequently, resins displaying greater degrees of polymerization may provide substantial clinical advantages.<sup>13</sup> The injection molding technique also provides a long working time before polymerization was complete, and this helps to improve the penetration of resin into space between fibres.<sup>11,24,25</sup>

### Failures of Nylon as Denture Base

They can therefore be ascribed due to the following causes; the material has a very high water sorption and is rather flexible. Processing conditions are generally far from optimum, particularly mould temperature and injection pressure.<sup>10</sup>

### Improvements in nylons necessary for intra-oral potential

Processing must be under precise control, since the sensitivity of polyamides to method of molding can give up to a 50 percent variation in crystallinity, which markedly affects the mechanical properties. In 1962 there was a further advance in the polyamide field with the introduction of glass reinforcement of base nylon, of the 'short-fibres' types. The success of this has been largely due to the silane-treatment of the glass fibres so that the bonding occurs with the base material. Both the strength and the stiffness are increased, the tensile strength being doubled and the modulus of elasticity becoming three and half times greater. The coefficient of linear expansion is reduced to a quarter of its previous value and this would enhance dimensional stability both in processing and in use. The water sorption value is lowered by a diluent effect to 1.2 percent.<sup>10</sup>

According to Katsumata et al silica-coating by Rocatec system was effective in improving the bond strength of nylon denture base polymer to autopolymerizing repair resin.<sup>26</sup> Polyamide has some attractive advantages, but will require modification to produce consistently better properties than current PMMA materials.<sup>15</sup>

### Dental applications for thermoplastic resins

Current dental applications for thermoplastics resins originally involve:<sup>27,28</sup>

1. Preformed partial denture clasp
2. Flexible tooth born partial denture framework
3. Single cast partial dentures
4. Temporary crowns and bridges
5. Gum veneers
6. Space maintainers
7. Immediate dentures
8. Replacement of missing teeth in pediatric cases
9. Precision attachment
10. Combination with metal framework
11. Occlusal appliances
12. Implant abutments
13. Orthodontic and sleep apnea appliances
14. TMJ appliances



## Conclusion

The dentists today have to meet growing demands for prosthetic rehabilitation due to population aging and higher requirements on the quality of life. That means higher demands on the functional reliability of dental appliances, their aesthetical and biological properties. Dental research teams and industry are looking for new materials with properties very similar to natural oral tissues, requiring simple handling. The new materials involve new technologies and devices which are being introduced into practical dental work from cosmic and other hi-tech projects. Modern technologies bring both expensive systems (ceramics, titanium, dental implants), and cost-saving solutions (plastic materials). The offer of materials and technologies is continuously growing on the dental market. Time and practical experience will help us in the choice of the best-quality materials and working procedures for prosthetic rehabilitation.

Thermoplastic resins have been used in dentistry for many years. During that time the applications have continued to grow and the interest in these materials by both the profession and the public have increased. The materials have superior properties and characteristics and provide excellent esthetic and biocompatible treatment options. With the development of new properties, there are certain to be additional new applications for thermoplastic resin in the future, to help patients with damaged or missing teeth.<sup>29</sup>

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