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Literature Review Article

Influence of material type and manufacturing methods on the quality of occlusal splints: a literature review

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Abstract

Introduction and Objective: This review aims to assess whether the type of material and method of manufacturing occlusal splints can influence their quality. **Material and methods:** The present review identify and select studies related to the methods of occlusal splint fabrication. The searches were conducted in the PubMed, SciELO, and Scopus databases. **Results:** Traditionally, occlusal splints have been fabricated with acrylic resin through techniques like muffle pressing, carving, or vacuum thermoforming. With the rise of digital dentistry, CAD/CAM technology has enabled the production of these devices using both additive and subtractive techniques. Besides acrylic resin, materials such as polymethyl methacrylate (PMMA), ethylene vinyl acetate (EVA), polyethylene terephthalate glycol (PETG), and polycarbonate (PC) are also utilized. Recently, a high-performance polymer called PEEK has been introduced in dentistry for fixed and removable prostheses and is considered a promising material for interocclusal devices. **Conclusion:** The quality of occlusal splints can be influenced by post-polymerization processes, particularly in 3D printing, as incomplete polymerization may occur. Additionally, the polishing of these devices after manufacturing is crucial, as insufficient polishing can lead to cytotoxic effects, a concern also noted with 3D printing techniques. Current literature continues to evaluate the quality of occlusal splints in terms of hardness and durability.

Introduction

The literature indicates that occlusal splints are the primary treatment for mitigating the effects of bruxism and temporomandibular disorders [8-10, 12, 15, 17]. These devices cover the entire occlusal surface of the teeth in an arch and can be made from various materials and manufactured using different methods [2]. The selection of materials should meet biocompatibility standards and ensure durability, as the splints must withstand occlusal forces resulting from parafunctions [5].

Traditionally, occlusal splints have been made using self-polymerizing or thermo-polymerizing acrylic resin through muffle pressing, sculpting, or vacuum thermoforming [9, 10, 15]. However, with the increasing digitalization of dentistry, new materials and manufacturing methods, such as CAD/CAM technology, have been developed for intraoral devices.

The CAD/CAM system, which stands for Computer-Aided Design/Computer-Aided Manufacturing, is gradually replacing conventional methods [2, 10]. This system involves creating a model of the splint using oral scanning or conventional molding, which is then digitized. Two manufacturing techniques are possible: subtractive and additive. The subtractive technique involves milling a prefabricated piece (disc or block) to achieve the desired shape, which results in more material waste. In contrast, the additive technique uses 3D printing with a liquid resin that is polymerized layer by layer, producing less waste [9, 10].

Various materials are considered for occlusal splints, including polymethyl methacrylate (PMMA), ethylene vinyl acetate (EVA), polyethylene terephthalate glycol (PETG), and polycarbonate (PC), with PMMA being the most commonly used[7]. Recently, a high-performance polymer called PEEK has been introduced in dentistry for fixed and removable prostheses and is being considered for interocclusal devices due to its excellent properties [5, 18].

Post-polymerization is a factor that can influence the quality of these devices, especially when using 3D printing, as incomplete polymerization can occur [15]. Another important aspect mentioned in the literature is the polishing of the device after manufacturing, as insufficient polishing can lead to cytotoxic effects, which is also noted in 3D printing techniques [4]. The wear and surface hardness of occlusal splints are also analyzed based on the manufacturing technique used [8]. This review aims to assess whether the type of material and method of manufacturing occlusal splints can influence their quality.

Material and methods

The present review adopted a systematic search to identify and select studies related to the methods of occlusal splint fabrication. The searches were conducted in the PubMed, SciELO, and Scopus databases.

The following keywords were used for study selection: *occlusal splint*, *intraoral splint device*, *interocclusal splint*, *CAD/CAM technology*, and *digitized dentistry*.

The inclusion criteria encompassed original studies, systematic reviews, and randomized clinical trials that addressed methods for fabricating occlusal splints, both manual and digital. The initial screening was based on titles and abstracts, followed by a full-text analysis to verify eligibility according to the established criteria. The extracted data included information on the materials used, fabrication techniques (manual or digital), and the advantages and limitations of the methods described.

Results

Materials used in the fabrication of occlusal splints

PMMA (polymethylmethacrylate)

Although widely used, heat-activated and self-polymerizing acrylic resins have certain disadvantages, including the release of monomers that can lead to surface and internal porosity, color instability, and reduced rigidity and fracture resistance. Potential for irritation and unfavorable taste[3], while reported that the residual monomer released from self-polymerizing resins can cause redness, pain in the oral mucosa, and edema [1].

The link between incomplete polymer conversion and the risk of reactions in methacrylate-based materials such as PMMA was investigated. The study evaluated the toxicity and release of residual monomers and additives. To simulate physiological intraoral conditions, distilled water and methanol were used as solvents. The specimens were immersed in 1 ml of each solution at 37ºC and analyzed after 24 and 72 hours. The authors concluded that under normal intraoral physiological conditions, no significant cytotoxic effects are expected from any of the tested materials, regardless of the technique used [20].

In addition to residual monomers, PMMA can deteriorate over prolonged use, a phenomenon observed in dental prosthetics. This deterioration can occur gradually due to physical-chemical factors such as occlusal forces and thermal stress. The superficial layers of the material could deteriorate more rapidly due to the influence of salivary enzymes and bacterial metabolic activity, which may induce chemical reactions altering the structure. While their research focused on the surfaces of complete dentures used for 2 to 10 years, similar effects might occur in intraoral devices made from PMMA, as they are also used daily and for extended periods, particularly in the treatment of bruxism [11].

Photoactivated acrylic resin

Light-activated acrylic resin is not commonly used in the manufacture of occlusal splints, but it has been explored as a potential option due to its quick and practical application process [22]. A literature review conducted in 2021 [6] on the types and properties of materials used for interocclusal devices show that photopolymerizable acrylic resins offer several advantages, including a lower amount of residual monomer, good chemical stability, absence of unpleasant taste, adequate hardness, and reduced polymerization shrinkage compared to self-polymerizing resins.

Wear resistance of any resin is influenced by its surface microhardness, which in turn depends on the degree of polymer conversion. A study compared the surface microhardness of light-cured and self-cured acrylic resins, finding that light-cured resins not only met but sometimes exceeded the characteristics of self-cured resins, making them suitable for occlusal splints. The advantages of using photopolymerizable resins for these devices include excellent handling characteristics, good dimensional stability, a low elution rate of organic solvents and monomers, and a reduced production time compared to self-polymerizing resins. However, they must have a sufficient filler content to ensure fracture resistance [5].

PEEK (polyetheretherketone)

A new material recently introduced into dentistry is the high-performance polymer polyetheretherketone, better known as PEEK. Due to its high thermal stability, wear resistance, biocompatibility, low affinity for plaque, and other favorable properties, PEEK has been explored as a promising material for making prostheses [18].

Comparative study in five different types of resins – EVA, PMMA, PETG, PEEK, and PC – in terms of volume loss, surface roughness after polishing, and wear following a chewing simulation. Using CAD software, they designed cylindrical specimens (2mm thick and 10mm in diameter), a total of 75 in number, made from each type of resin and milled using the subtractive technique (CAM). The results showed that surface roughness and volume loss varied between materials. EVA had the highest levels of both surface roughness and volume loss, and it also showed more wear compared to polycarbonate and PMMA. PEEK demonstrated the best overall performance, suggesting it could be a new material option for occlusal splints [2].

Methods for making occlusal splints

With advancements in technology, different manufacturing techniques have been introduced for producing occlusal stabilizer splints. A notable example is the use of CAD/CAM technology, which stands for computer-aided design and manufacturing. This technology is gradually replacing conventional methods, as it offers a more streamlined workflow [10, 13, 15-17, 20].

In traditional manufacturing, several steps are involved, which can increase the likelihood of errors and distortions [19]. The dental surgeon typically takes an impression of the patient's arches (usually with alginate), records the bite, and creates a model (often with plaster) or sends it to a lab for fabrication. The occlusal splint is then made from acrylic resin, usually in powder and liquid form [14].

The digital method, on the other hand, begins with an intraoral scan of the patient, capturing all relevant anatomical structures. This replaces the traditional impression or can be performed in the lab after a conventional impression is taken [16, 17].

The prosthetics lab manufactures the occlusal splint using subtractive or additive tecnique. In the subtractive method, there is more material waste, as the splint is milled from a prefabricated block, requiring grinding to achieve the desired shape. In the additive method, the interocclusal device is created in a 3D printer using liquid resin, which is polymerized layer by layer. Only the support structure is removed, allowing for multiple parts to be manufactured simultaneously, resulting in less waste [9, 16].

Occlusal splints made using the additive technique may have lower clinical performance than those produced through milling. In their study, they compared different materials used in 3D printing with conventional milling materials, focusing on the effects of post-polymerization, artificial aging, and hardness [15].

The post-polymerization is crucial for printed resins, as these materials are not fully polymerized during the printing process [15].

Discussion

Regardless of the material and technique chosen, occlusal devices must meet specific mechanical requirements for clinical practice. They should be able to withstand forces exceeding 770N and resist the impacts associated with grinding and clenching [8, 15].

Acrylic resin, both self-polymerizing and heat-activated, is the most commonly used material for rigid occlusal splints [10]. One disadvantage of acrylic is the incomplete polymer conversion and monomer release, which can cause irritation such as redness and edema, and also impart an unpleasant taste [1, 9].

However, Wedekind *et al.* [20] concluded that under normal intraoral physiological conditions, undesirable cytotoxic effects are not expected.

Acrylic resin can deteriorate over time, as observed in studies on dental prostheses, and the same is likely for occlusal splints [11]. Another factor affecting the longevity of these devices is wear resistance, which depends on the surface's microhardness and the degree of polymer conversion [5]. Good chemical and dimensional stability, adequate hardness, lower residual monomer content, and the absence of an unpleasant taste make light-activated resins a promising, albeit less common, material for oral devices [5, 6].

Another recent material is PEEK (polyetheretherketone), a high-performance polymer known for its thermal stability, wear resistance, and low affinity for oclusal splint [13, 18]. PEEK could be a viable alternative to conventional acrylic resin due to its favorable properties [2].

Traditional occlusal splint fabrication involves several steps, increasing the risk of errors and distortions. However, the advent of CAD/CAM technology allows for computer-aided design and production of occlusal splints. The impressions can be taken conventionally and sent to the laboratory in physical form, or captured using an intraoral scanner, which then generates a digital file. Patzelt *et al.* [14]. Digital techniques significantly reduce preparation time in the laboratory phase [2, 3, 7, 14].

The digital method includes two main techniques: additive (3D printing) and subtractive (milling). Studies suggest that both methods have similar properties, but the subtractive technique often yields better results. Reymus and Stawarczyk [15] observed that the additive method is more susceptible to artificial aging and changes in elastic properties after prolonged water storage, increasing the risk of fracture. They also noted that the absence of post-polymerization could affect the viscoelasticity of the device, leading to deformation over time.

Berli *et al.* [2] reported lower flexural strength, hardness, and higher water solubility in printed resins compared to milled ones. Both authors raised concerns about the quality of 3D-printed oral devices but acknowledged that more research is needed as the technology is still evolving. Marcel *et al.* [10] found no significant difference in the accuracy of occlusal splints made using either method for clinical practice. Technique used could influence the surface hardness and wear of the oral device, but more recent studies did not find significant differences between digital and conventional methods in terms of wear [8, 14, 21].

The biological behavior of printed resins is less well understood compared to their mechanical properties. Splints made using the additive technique could have cytotoxic effects if not polished, but this risk is mitigated if polishing is performed, aligning their safety with that of specimens made using conventional or milling techniques [4]. However, the authors noted that it is not always feasible to polish certain areas, such as the occlusal surface of occlusal splints, without losing the contact point. Consequently, they suggest that printed resin devices may be more suitable for short-term use, such as surgical guides, rather than long-term applications like occlusal splints.

Conclusion

Regarding the material, light-activated resins and PEEK, despite not being commonly used in the production of occlusal splints, seem to be good options as they have interesting qualities. However, more studies need to be done with the aim of providing reliability to the material. its use for this purpose.

Regarding the quality of interocclusal devices and technique, studies show that there is no significant difference between conventional and digital, however, the laboratory phase of digital splints tends to be faster than non-digital flow, which can be an advantage for the clinical routine.

When comparing printed and milled splints, milled splints present better results in terms of physical-chemical properties, as printed splints are more susceptible to artificial aging, have greater solubility in water, lower flexural strength and hardness value.

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