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Analysis of the Properties and Application Status of Novel Impression Materials in Digital Dental Practice

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ABSTRACT

The advent of digital dentistry has revolutionized traditional workflows, with intraoral scanning (IOS) emerging as a cornerstone for direct digital impression acquisition. However, conventional impression materials remain indispensable, particularly for specific clinical scenarios. This review analyzes the properties and application status of novel impression materials developed for and alongside digital technologies. It focuses on the evolution of polyvinyl siloxane (PVS) and polyether (PE) materials, the emergence of hybrid and modified materials, and the growing role of scannable silicones and 3D printing resins. The article evaluates their key performance characteristics—such as dimensional accuracy, stability, hydrophilicity, and compatibility with digital workflows—and discusses their clinical applications in fixed prosthodontics, removable prosthodontics, and implant dentistry. Finally, the challenges and future trends, including the integration of bi-functional materials and additive manufacturing, are explored.

KEYWORDS

Intraoral scanning; Polyvinyl siloxane; Prosthodontics

1. INTRODUCTION

Dental impressions are a critical first step in creating accurate restorations and appliances.The digital transformation in dentistry, led by intraoral scanners, has shifted the paradigm from physical impressions to virtual models [1]. Despite the rapid adoption of IOS, physical impressions are far from obsolete. They are still required for cases involving subgingival preparations, full-arch implants, and when utilizing specific laboratory techniques [2]. Furthermore, the digital workflow itself often relies on physical models printed from digital data, for which "scannable" materials are essential. This review aims to provide a comprehensive analysis of the novel impression materials that have evolved to meet the demands of modern, digitally-integrated dental practice, examining their properties and current clinical applications.

2. CLASSIFICATION AND PROPERTIES OF NOVEL IMPRESSION MATERIALS

2.1. Enhanced Elastomers: PVS and PE

Traditional workhorses like Polyvinyl Siloxane (PVS) and Polyether (PE) have been significantly improved.PVS (Addition Silicone): Known for their excellent dimensional accuracy and stability, low shrinkage, and high tear strength. Newer formulations offer enhanced hydrophilicity for better wet-field detail capture, faster setting times, and improved flowability [3].

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Polyether: Renowned for their inherent hydrophilicity and rigid accuracy. Recent developments have focused on reducing their taste, improving their stiffness (which can be a challenge in undercut areas), and creating softer, more user-friendly versions [4].

2.2. Hybrid and Modified Materials

To integrate the optimal characteristics of diverse materials, researchers have developed hybrid materials. Vinyl Polyether Siloxane (VPES) stands as a prominent example: this category of materials successfully combines the high precision and stability of Polyvinyl Siloxane (PVS) with the excellent hydrophilicity of Polyether (PE). VPESmaterials exhibit exceptional performance in wet surface detail reproduction, with extremely low shrinkage rates, and offer easier handling compared to traditional polyether materials. These attributes position VPES as a versatile option suitable for both conventional and digital workflows, enabling widespread application across various scenarios and significantly enhancing work efficiency and product quality [5].

2.3. Scannable Impression Materials

A direct response to the digital workflow,these materials are formulated to be optically ideal for laboratory scanners. Scannable Silicones: These are typically PVS materials with specific colorants (often white, light grey, or pastel shades) and low reflectivity/transluency. This provides high contrast against the prepared tooth, minimizing scanning errors and ensuring the creation of a highly accurate digital model from the physical impression [6]. 3D Printing Resins (for Models): While not impression materials per se, resins used to print dental models from digital impressions are a crucial part of the chain. Their properties—such as dimensional stability, surface hardness, and minimal curing shrinkage—directly impact the final restoration's fit [7].

3. KEY PERFORMANCE CHARACTERISTICS IN THE DIGITAL CONTEXT

Dimensional Accuracy and Stability: This is the most crucial property to consider. Materials must demonstrate an exceptionally low level of permanent deformation and shrinkage over an extended period, such as 24 hours, to guarantee that the digital model or the physical cast maintains its precise alignment and fidelity to the actual intraoral conditions. This stability is imperative to ensure that the final product accurately reflects the intricate details of the oral cavity, as any deviation could compromise the effectiveness of the dental restoration or appliance .

Hydrophilicity: This characteristic is of paramount importance for capturing the finest details in the often moist environment of the mouth, which may contain saliva, blood, or gingival sulcular fluid. Hydrophilic materials are designed to effectively displace these moisture elements, thereby minimizing the formation of voids and defects in the impression. This property ensures that the impression is both accurate and reliable, providing a clear and detailed representation of the oral structures [3].

Tear Strength and Elastic Recovery: These attributes are indispensable for the precise recording of complex oral anatomy, such as deep subgingival margins and undercuts. Materials with high tear strength and elastic recovery can be stretched and manipulated without tearing or undergoing permanent deformation when removed from the mouth. This ensures that the impression remains intact and accurately reflects the intricate details of the oral cavity, which is essential for the success of subsequent dental procedures .

Working and Setting Time: The optimization of these times is critical for achieving both clinical efficiency and patient comfort. The working time must be sufficient to allow the dental professional to manipulate and position the material accurately, while the setting time should be rapid enough to

minimize the risk of errors caused by patient movement. Striking the right balance between these times is essential to ensure that the impression process is both effective and patient-friendly.

Digital Compatibility: For materials that are intended to be scanned, this property pertains to their optical characteristics, which must be conducive to accurate digital capture. For all materials, digital compatibility also involves the ability to be poured with gypsum or scanned without generating any artifacts that could interfere with the digital workflow. This ensures a seamless integration into the digital process, allowing for efficient and accurate transfer of the impression data into digital models, which is crucial for modern dental practices [6].

4. CURRENT CLINICAL APPLICATIONS

4.1. Fixed Prosthodontics (Crowns and Bridges)

In the realm of fixed prosthodontics, particularly when dealing with crowns and bridges, the utilization of innovative impression materials has become paramount. Specifically, high-accuracy polyvinyl siloxane (PVS) and vinyl polyether silicone (VPES) have emerged as the gold standard for multi-unit fixed prostheses. Their unparalleled dimensional stability is of utmost importance, especially for ensuring the passive fit of long-span bridges, which require precise alignment to avoid mechanical stress. Additionally, scannable silicones have gained widespread adoption in dental laboratories. These materials are instrumental in creating definitive models that serve as the basis for digital design, thereby enhancing the overall precision and efficiency of the prosthodontic process.

4.2. Removable Prosthodontics (Dentures)

In the context of removable prosthodontics, particularly in the fabrication of dentures, intraoral scanning (IOS) is gradually gaining traction for edentulous impressions. However, conventional impression materials continue to be extensively employed for final impressions in complete denture therapy. This persistence is largely due to their unparalleled ability to accurately record the functional aspects of the oral mucosa, which is crucial for the comfort and fit of the denture. High-performance silicones and polyethers are particularly favored for their exceptional accuracy, making them indispensable for both traditional processing methods and the fabrication of digitally designed trial dentures. These materials ensure that the final prosthesis closely mimics the natural contours of the patient's mouth, thereby enhancing functional outcomes [2].

4.3. Implant Dentistry

Precision is an absolute necessity in the field of implant dentistry, where even minor discrepancies can lead to significant clinical complications. Both open-tray and closed-tray impression techniques for multiple implants heavily rely on materials that exhibit high elastic recovery and minimal deformation. Polyvinyl siloxane (PVS) is a prime example of such a material, as it excels in accurately capturing the spatial position of implant analogs. This precision is critical for the successful integration of the implant with the surrounding tissues. Moreover, the digital workflow in implant dentistry often involves scanning a model that has been created from a high-precision impression, thereby bridging the gap between traditional and digital techniques and ensuring a seamless transition.

4.4. Digital Workflow Integration

The integration of novel impression materials into a fully digital or hybrid workflow plays a pivotal role in modern dental practice. These materials serve as a reliable and accurate fallback option when intraoral scanning proves to be challenging, ensuring that the workflow can continue without compromising on precision [1]. Furthermore, the physical master cast derived from a scannable impression serves as the foundational element for the digital design process. This master cast ensures

that the virtual model is an exact replica of the patient's anatomical structures, thereby facilitating the creation of highly accurate and customized dental prostheses. The synergy between traditional impression techniques and digital technologies underscores the importance of these materials in enhancing the overall efficacy and reliability of dental workflows [6].

5. CONCLUSION

In recent years, novel impression materials have undergone substantial advancements, firmly establishing their pivotal role in the rapidly evolving digital dental landscape. These materials have been meticulously developed to offer a myriad of enhanced properties, including significantly improved accuracy, exceptional stability, superior hydrophilicity, and seamless digital compatibility. Among these cutting-edge materials, advanced Polyvinyl Siloxane (PVS), Polyether (PE), Vinyl Polysiloxane Ether (VPES), and scannable silicones have emerged as indispensable tools in modern dental practice. These innovative materials serve as a crucial bridge between the tangible physical reality of dental impressions and the sophisticated digital workflow, thereby ensuring unparalleled reliability and precision, especially in complex and challenging clinical cases. As the field of digital dentistry continues to progress and innovate, the harmonious integration and synergy between these state-of-the-art impression materials and emerging technologies, such as 3D printing, will undoubtedly play a central role in shaping the future of restorative and prosthetic dentistry. This ongoing collaboration promises to elevate the standards of dental care, offering more efficient, accurate, and patient-friendly solutions.

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