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IMPACT OF SUBSTRUCTURAL COMPOSITION ON THE FIDELITY AND DIGITIZATION EFFICIENCY OF IMPLANT-SUPPORTED FULL-ARCH FRAMEWORK SUBSTRUCTURES

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Abstract

Within the digital workflow for full-arch implant-supported fixed restorations, the bar substructure serves as a foundational element upon which aesthetic suprastructures are cemented. In certain clinical scenarios, intraoral digitization of these substructures is necessary; however, the scanning performance and dimensional reliability of different bar materials remain incompletely characterized (Rutkunas et al., 2021). This study aimed to evaluate and compare the scanning efficiency and accuracy of two materials used in implant-supported bar frameworks: titanium and polyetheretherketone (PEEK).

A maxillary edentulous patient with four integrated implants received two identical bar substructures milled via CAD/CAM—one from titanium and one from PEEK. Each substructure was digitized using a laboratory-grade desktop scanner to produce a reference stereolithography (STL) file. Subsequently, each bar underwent ten intraoral scans using a standardized protocol with a defined time constraint.

Scannability was assessed by measuring the surface area (mm²) captured within 15 seconds (Emam et al., 2023). Dimensional accuracy was evaluated by calculating root mean square (RMS) deviation (µm) between intraoral scans and the reference. Trueness was derived from scan-to-reference alignment, and precision from pairwise scan comparisons.
Results showed that the titanium substructure exhibited significantly superior trueness (202.40 ± 27.57 µm) and precision (197.50 ± 24.69 µm) compared to PEEK (262.20 ± 30.87 µm and 244.14 ± 9.18 µm, respectively; $P < 0.001$). Conversely, PEEK demonstrated greater scannability, with a larger mean captured surface area (985.42 ± 7.22 mm²) versus titanium (951.15 ± 12.16 mm²; $P < 0.001$).
These findings indicate that material selection for implant substructures involves a trade-off between scanning efficiency and dimensional fidelity. While PEEK supports faster and more complete optical capture, titanium provides higher geometric accuracy, essential for passive prosthetic fit (Lin et al., 2015). Clinicians should select materials based on clinical priorities: titanium when precision is paramount, and PEEK when scanning efficiency is prioritized.

Keywords: Scanning accuracy, digitization efficiency, PEEK, titanium, implant-supported prosthesis, trueness, precision, intraoral scanning.

Introduction

Digital workflows in implant prosthodontics have increasingly incorporated intraoral scanning for both diagnostic and restorative phases. Full-arch implant-supported rehabilitations often employ a bar substructure design, which may require intraoral digitization for suprastructure fabrication or verification. The accuracy of such scans is influenced by numerous factors, including scanner technology, operator technique, ambient conditions, and—critically—the optical

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properties of the scanned material (Abduo & Elseyoufi, 2018; Revilla-León et al., 2020).

While titanium remains a gold standard for implant frameworks due to its strength, biocompatibility, and clinical longevity, polyetheretherketone (PEEK) has emerged as a viable non-metallic alternative, offering favorable mechanical and optical characteristics (Mizumoto & Yilmaz, 2018). However, the comparative performance of these materials in terms of intraoral scanning efficiency (scannability) and dimensional accuracy remains underexplored in clinical settings. This study therefore aimed to evaluate the scanning accuracy and scannability of titanium and PEEK bar substructures in a controlled intraoral environment, with the null hypothesis that no significant differences would exist between the two materials in either metric.

Methods

A maxillary edentulous patient with four osseointegrated implants was selected. Two identical bar substructures were fabricated via CAD/CAM milling—one from titanium and one from PEEK. Each substructure was digitized using a laboratory-grade desktop scanner to generate a reference stereolithography (STL) file. Subsequently, each bar was subjected to ten intraoral scans using a standardized scanning protocol with a defined time constraint.

Fig. 1. A fully anatomic try-in for esthetics and occlusion verification.

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Scannability was quantified by measuring the surface area (mm²) captured within a 15-second interval (Emam et al., 2023). Dimensional accuracy was assessed by calculating the root mean square (RMS) deviation (µm) between each intraoral scan and the corresponding reference scan, with trueness derived from scan-to-reference comparisons and precision derived from pairwise comparisons among intraoral scans (Mangano et al., 2016).

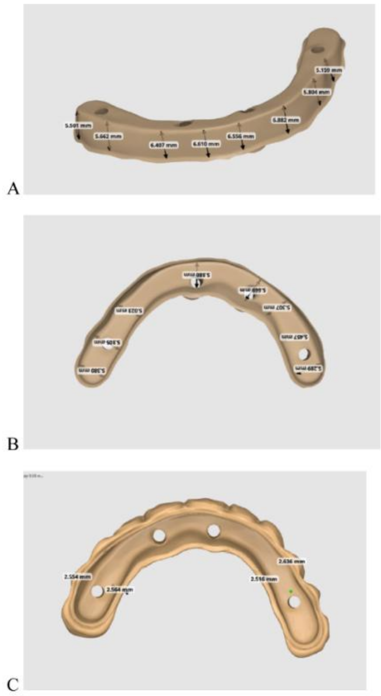

Fig. 2. Supra and substructure dimensions. **(A)** Occluso-cervical height. **(B)** Bucco-palatal width. **(C)** 2.5 mm thick suprastructure dimensions.

Results

The titanium substructure exhibited significantly superior trueness (202.40 ± 27.57 µm) and precision (197.50 ± 24.69 µm) compared to the PEEK substructure (262.20 ± 30.87 µm and 244.14 ± 9.18 µm, respectively; $P < 0.001$). Conversely, the PEEK framework demonstrated significantly greater scannability, with a

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larger mean captured surface area (985.42 ± 7.22 mm²) within the allotted time relative to titanium (951.15 ± 12.16 mm²; $P < 0.001$).

Discussion

This study demonstrates that substructure material significantly influences both the accuracy and efficiency of intraoral scanning in full-arch implant-supported cases. The titanium framework yielded superior trueness and precision, likely attributable to its edge definition and reduced optical noise following surface abrasion. These findings align with prior reports indicating higher scanning accuracy for titanium scan bodies compared to polymer-based alternatives (Azevedo et al., 2024; Baranowski et al., 2025).

In contrast, PEEK exhibited higher scannability, capturing more surface area within a limited time. This may be explained by its matte, low-reflectivity surface, which facilitates light absorption and dense point-cloud generation by the intraoral scanner (Kurz et al., 2015). This result is consistent with earlier in vitro work identifying PEEK as a highly scannable material (Emam et al., 2023).

Clinically, these outcomes highlight a trade-off: titanium should be preferred when prosthetic fit and passive placement are critical, whereas PEEK may enhance workflow efficiency in time-sensitive or optically challenging scanning situations. The absence of a direct correlation between scannability and accuracy underscores the need for material selection based on specific clinical objectives.

Limitations

This study was conducted on a single patient to control inter-individual variability, which may limit generalizability. Only two materials were tested, and all scans were performed under ideal ambient conditions. Future research should evaluate additional materials, varied clinical environments, and the impact of scanning accuracy on final prosthesis fit.

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Conclusion

1. Titanium bar frameworks produced scans with higher trueness and precision than those made from PEEK.
2. PEEK frameworks demonstrated greater scannability, with less surface area omitted during time-limited scanning.
3. No direct correlation exists between scanning accuracy and scannability, underscoring the need for case-specific material selection in digital implant prosthodontics.

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