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Comparative Evaluation of the Durability of CAD/CAM Fabricated Crowns Using Two Materials, PEEK and High-Strength Ceramic: An Original Research Study

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ABSTRACT:

Aim: This study aims to evaluate the durability of CAD/CAM fabricated crowns using two materials, PEEK and high-strength ceramic.

Materials and Methods: This study examines the durability of CAD/CAM fabricated crowns made from two materials: PEEK (Polyether Ether Ketone) and high-strength ceramics. Sixty crowns were produced, split into two groups of 30 each. Group 1 consists of PEEK crowns, known for strength and biocompatibility, while Group 2 includes high-strength ceramic crowns, valued for aesthetics and resistance to force. Both groups underwent systematic testing using a universal testing machine to simulate real-life stresses. The crowns were created from standardized epoxy resin dies, replicating a mandibular first molar, with designs generated using CAD software Exocad and milled from BioHPP and IPS e.max CAD materials. After being cemented with a controlled force of 40N, the crowns underwent mechanical aging and thermocycling. Their durability was then tested by applying a compressive load until failure.

Statistical Analysis and Results: This study analyzes the durability of 60 CAD/CAM crowns across two materials. Group 1 features PEEK (polyetheretherketone) crowns, known for their strength and biocompatibility, demonstrating impressive resilience under various conditions. Group 2 consists of high-strength ceramic crowns, prized for their aesthetic properties and durability. The study evaluated the performance of two groups of materials: Group 1 consisted of PEEK with a sample size of 30, while Group 2 comprised ceramics, also with 30 samples. The findings revealed that PEEK exhibited superior mechanical properties, including a durability of 809 N (±35.96), fracture strength of 810 N (±95.18), and a compressive strength of 825 N (±69.15). In contrast, the ceramics group demonstrated lower values, with durability measured at 712 N (±112.24), fracture strength at 724 N (±198.36), and compressive strength at 803 N (±29.58). Statistical analyses, including the Pearson Chi-Square test and one-way ANOVA, indicated significant differences in the strengths and weaknesses of these materials, highlighting the advantages of PEEK over ceramics.

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Conclusion: The study concluded that high-strength ceramics like Zirconia had superior fracture resistance and longevity in high-stress areas, while PEEK effectively absorbed stress, reducing wear on opposing teeth and enhancing overall durability.

Introduction

CAD/CAM dentistry, which stands for Computer-Aided Design and Computer-Aided Manufacturing, revolutionizes the way dental restorations are created by integrating advanced technology with traditional dental practices. This innovative approach enables the design and production of high-precision dental restorations including crowns, veneers, inlays, onlays, and bridges often within a single visit to the dentist. By utilizing sophisticated 3D chair side scanners and automated milling machines, CAD/CAM systems enhance efficiency and accuracy, drastically improving the patient experience.[1,2] This technology replaces the need for traditional, uncomfortable impressions that can be unpleasant for patients, opting instead for seamless digital workflows that provide a clear and precise representation of the patient's dental structure. The durability of dental crowns is assessed through careful monitoring for various signs of wear and degradation. Indicators that a dental crown may be failing include the presence of chips or cracks, visible gaps forming between the tooth and the crown, and symptoms like pain or heightened sensitivity.[3,4] Additionally, patients may experience a "high" bite sensation indicating improper alignment, or the crown might begin to feel loose. Regular professional dental examinations every six months are crucial, as they help identify underlying issues such as decay or damage that may not be immediately visible but could compromise the integrity of the restoration. CAD/CAM crowns made from PEEK (polyetheretherketone) represent a significant advancement in dental materials, offering a high-performance, biocompatible, and lightweight option compared to traditional metals and zirconia.[5,6] PEEK crowns possess elastic properties that closely mimic those of natural dentin, providing a balance of strength and flexibility. When milled using CAD/CAM technology, these crowns exhibit excellent wear resistance and shock-absorbing qualities, thereby reducing stress on opposing teeth and mitigating the risk of further dental issues. This makes PEEK an excellent choice for long-term temporary solutions or molar restorations, especially when combined with aesthetic composite veneers to enhance visual appeal.[7,8] On the other hand, CAD/CAM crowns crafted from high-strength ceramics, such as zirconia and lithium disilicate, are celebrated for their superior durability, impressive fracture resistance, and aesthetic translucency. These advanced materials are particularly suited for high-stress dental applications, often demonstrating fracture toughness that surpasses that of traditional restorative materials. The digital design process, paired with precise milling techniques, allows for the creation of restorations that not only last longer but also offer a natural-looking appearance that blends seamlessly with the surrounding teeth. Specifically, CAD/CAM ceramic crowns made from zirconia are known for their longevity, often exceeding 20 years of functional use without significant degradation.[9,10] Their high fracture strength makes them the material of choice for areas that experience substantial biting forces. In comparison, while PEEK offers better elasticity and results in less wear on antagonist teeth, it generally necessitates the use of composite veneering to achieve the desired aesthetic outcomes. Moreover, PEEK has a lower ultimate fracture strength compared to zirconia, which makes it particularly suited for provisional or implant-supported posterior crowns where the demands on the material may differ from those required for anterior restorations.[11] This study aims to evaluate the durability of CAD/CAM fabricated crowns using two materials, PEEK and high-strength ceramic.

Materials and Methods

This study delves into the durability of CAD/CAM fabricated crowns crafted from two distinct materials: PEEK (Polyether Ether Ketone) and high-strength ceramics. A total of 60 meticulously designed crowns were produced, with an equal division into two groups, each containing 30 crowns. The objective of this research is to compare the performance of these two groups, assessing their durability under controlled testing conditions. Group 1 comprises crowns made from PEEK, a versatile and resilient thermoplastic known for its outstanding strength and biocompatibility. In contrast, Group 2 features crowns constructed from high-strength ceramics, materials renowned for their aesthetic appeal and ability to withstand significant forces. To rigorously evaluate their durability, both groups of crowns are subjected to systematic testing using a universal testing machine, which simulates the stresses that crowns endure in real-life dental applications. The fabrication process for these crowns begins with the creation of a precisely calibrated standard die, which replicates the anatomical structure of a mandibular first molar. This die is crafted from epoxy resin, serving as a reliable foundation for the subsequent crown production. The findings from this

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study aim to provide valuable insights into the performance characteristics of these materials in dental restorations. To initiate the scanning and designing process, the prepared tooth is carefully scanned using advanced imaging technology from Dentsply Sirona. Subsequently, a standardised anatomical crown design is generated using the CAD software Exocad. This design incorporates precise dimensions and maintains a uniform thickness of 1.5 mm across the crown. The crowns are then milled from high-quality CAD/CAM blocks—PEEK blocks like BioHPP for Group 1 and ceramic blocks such as IPS e.max CAD for Group 2. This milling process is performed on a sophisticated 5-axis milling machine, ensuring high accuracy and detail in the final product. After milling, the crowns are securely cemented onto the prepared dies utilizing a standardized bonding technique. A controlled force of 40N is applied for duration of 3 minutes using resin cement, such as RelyX U200, to ensure optimal adhesion. To simulate real-life oral conditions and evaluate mechanical durability, the specimens undergo mechanical aging. Additionally, thermocycling is performed. The durability is tested using a universal testing machine (UTM). The specimens are mounted in a manner that aligns the long axis of the die-crown assembly parallel to the crosshead of the machine. A spherical indenter, with diameters typically ranging from 3 mm to 4.24 mm, is positioned over the centre of the occlusal surface of the crown. A controlled compressive load is then applied at a consistent crosshead speed, typically between 0.5 to 1 mm/min, until the failure of the crown occurs. This study was to comprehensively evaluate and compare the mechanical performance and longevity of CAD/CAM fabricated crowns made from PEEK and high-strength ceramics, contributing valuable information to the field of restorative dentistry.

Statistical Analysis

In this study, we conducted all our statistical analyses utilizing SPSS version 31.0 software. This powerful statistical tool is particularly well-suited for managing and analyzing complex datasets in the social sciences, allowing us to draw meaningful insights from our data while ensuring accuracy and reliability in our results. To check if our findings were significant, we used the chi-square test. This test helps us compare the differences in proportions between groups, making it easier to see the trends and relationships in our data.

Results

This study conducts a comprehensive analysis of 60 CAD/CAM crowns, with a particular focus on their durability evaluated across two different crown materials. In Group 1, we examine crowns made from PEEK (polyetheretherketone), an advanced thermoplastic noted for its exceptional strength and biocompatibility. These attributes make PEEK an excellent option for dental applications. The PEEK crowns demonstrate outstanding resilience, ensuring a long-lasting performance even under varied conditions, which is crucial for maintaining dental functionality over time. Conversely, Group 2 comprises crowns constructed from high-strength ceramics, materials renowned for their aesthetic appeal and ability to withstand significant mechanical stresses. These ceramics not only closely resemble natural tooth enamel in appearance but also exhibit remarkable durability, solidifying their status as a favoured choice in restorative dentistry. Table 1 categorizes the total number of CAD/CAM fabricated crowns into these two distinct groups, providing a clear overview of the study's scope. Table 2 presents data for Group 1 (N=30), where the durability of the PEEK crowns was assessed using a universal testing machine. A statistical analysis utilizing the Pearson Chi-Square test facilitated the evaluation of the significance of the results, revealing an impressive durability measurement recorded at 809 (±35.96) N. Table 3 outlines the fracture strength of the PEEK crowns, also assessed with the universal testing machine under the same conditions as the durability test. The analysis again applied the Pearson Chi-Square test, and the resulting fracture strength was determined to be 810 (±95.18) N. Table 4 highlights the compressive strength of the PEEK crowns, evaluated in a similar manner. The statistical analysis through the Pearson Chi-Square test indicated a compressive strength of 825 (±69.15) N, further illustrating the mechanical performance of the PEEK material. Turning to Group 2, Table 5 details the durability of the high-strength ceramic crowns (N=30), assessed through the same universal testing machine. The results, analyzed with the Pearson Chi-Square test, indicated a durability of 712 (±112.24) N, showcasing a contrast to the PEEK crowns. In Table 6, the fracture strength of the high-strength ceramic crowns was analyzed, providing a measured value of 724 (±198.36) N after employing the Pearson Chi-Square statistical analysis to ascertain significance. Finally, Table 7 reports on the compressive strength of the high-strength ceramic crowns, evaluated using the same methodology, resulting in a compressive strength measurement of 803 (±29.58) N. To synthesize the findings from all studied groups, Table 8 utilizes a one-way ANOVA to estimate

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and compare the performance across the different materials, providing significant insights into their comparative strengths and weaknesses.

Table 1: The total number of CAD/CAM fabricated crowns has been categorised into two distinct groups

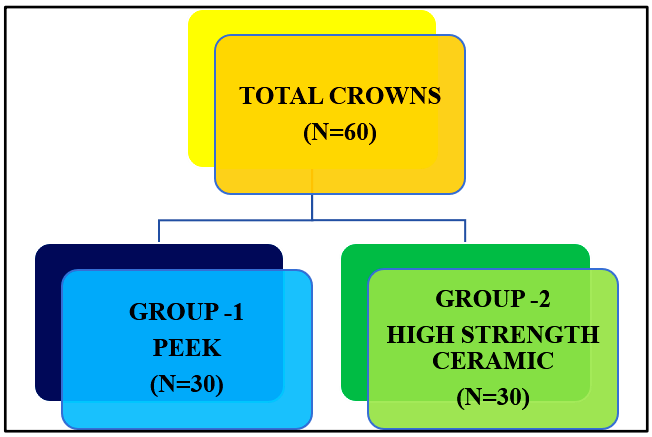

Table 2: Group 1 (N=30) The CAD/CAM crown was fabricated by PEEK, and its durability was evaluated using a universal testing machine. A statistical analysis was conducted with the Pearson Chi-Square test to determine the significance of the results

Evaluation factors	Stat. Mean	Std. Dev.	Std. Error	95 % CI	Pearson Chi-Square Value	df	p value
Durability	809 (±35.96)N	1.047	0.016	0.035	1.45	1.0	0.06712 (±112.24)N
*p<0.05 significant							

Table 3: Group 1 (N=30) The CAD/CAM crown was fabricated by PEEK, and its fracture strength was evaluated using a universal testing machine. A statistical analysis was conducted with the Pearson Chi-Square test to determine the significance of the results

Evaluation factors	Stat. Mean	Std. Dev.	Std. Error	95 % CI	Pearson Chi-Square Value	df	p value
Fracture strength	810 (±95.18) N	1.046	0.015	0.034	1.41	1.0	0.03*
*p<0.05 significant							

Table 4: Group 1 (N=30) The CAD/CAM crown was fabricated by PEEK, and its compressive strength was evaluated using a universal testing machine. A statistical analysis was conducted with the Pearson Chi-Square test to determine the significance of the results

Evaluation factors	Stat. Mean	Std. Dev.	Std. Error	95 % CI	Pearson Chi-Square Value	df	p value
Compressive strength	825 (±69.15)N	1.057	0.020	0.030	1.056	1.0	0.06
*p<0.05 significant							

Table 5: Group 2 (N=30) The CAD/CAM crown was fabricated from high-strength ceramic, and its durability was evaluated using a universal testing machine. A statistical analysis was conducted with the Pearson Chi-Square test to determine the significance of the results

Evaluation factors	Stat. Mean	Std. Dev.	Std. Error	95 % CI	Pearson Chi-Square Value	df	p value
Durability	712 (±112.24) N	1.017	1.021	1.024	1.023	1.0	0.43
*p<0.05 significant							

Table 6: Group 2 (N=30) the CAD/CAM crown was fabricated from high-strength ceramic, and its fracture strength was evaluated using a universal testing

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machine. A statistical analysis was conducted with the Pearson Chi-Square test to determine the significance of the results

Evaluation factors	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Fracture strength	724 (±198.36)N	1.014	0.13	0.97	1.099	1.0	0.02*
*p<0.05 significant							

Table 7: Group 2 (N=30) The CAD/CAM crown was fabricated from high-strength ceramic, and its compressive strength was evaluated using a universal testing machine. A statistical analysis was conducted with the Pearson Chi-Square test to determine significance of results

Evaluation factors	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Compressive strength	803 (±29.58) N	1.011	1.016	1.015	1.012	2.0	0.3*
*p<0.05 significant							

Table 8: Estimation amongst all studied groups using one-way ANOVA

Variables	Degree of Freedom	Sum of Squares ∑	Mean Sum of Squares m∑	F	Level of Sig. (p)
Between Groups	5	4.121	2.892	1.5	0.04*
Within Groups	16	2.454	1.892	–	
Cumulative	345.62	6.782	*p<0.05 significant		

Discussion

Davidowitz G et al reviewed in their study that CAD/CAM, which stands for Computer-Aided Design and Computer-Aided Manufacturing, has significantly transformed the field of dentistry by facilitating the creation of highly accurate dental restorations, including crowns, veneers, and bridges. This innovative technology replaces traditional impression techniques with advanced digital scanning methods and automated manufacturing processes. The CAD/CAM workflow in dentistry consists of three main steps that enhance the efficiency and accuracy of dental restorations.[12,13] Takaichi A et al showed in their study that first, data acquisition involves using an intraoral scanner to capture detailed three-dimensional images of a patient's dental anatomy, replacing traditional impression materials and minimizing discomfort. Next, the design customization stage allows dental professionals to utilize specialized software to craft tailored designs on-screen, which fosters creativity and ensures that each restoration meets the specific needs of the patient. Finally, the manufacturing step employs advanced techniques such as milling machines or 3D printing to produce the restorations, guaranteeing that they are precisely made according to the digital designs.[14,15] Wimmer T et al included that this technological approach offers numerous advantages, significantly improving the quality of dental care. One of the most significant benefits is the ability to perform single-visit dentistry, allowing patients to receive their restorations in just one appointment rather than needing multiple visits. Furthermore, the restorations produced using CAD/CAM is known for their precise fit, which enhances both comfort and functionality. This precision also contributes to a natural appearance, as digitally crafted restorations can closely mimic the aesthetics of natural teeth. Among the materials being utilized within the CAD/CAM framework, PEEK (polyether ether ketone) CAD/CAM crowns stand out due to their remarkable attributes.[16,17] Deste Gökay G et al showed in their study that PEEK is biocompatible, meaning it is well tolerated by the body, and it also exhibits properties that resist plaque accumulation and allergies, making it an ideal choice for patients with sensitivities. This material has a low elastic modulus, which provides excellent shock absorption, thereby offering added comfort during use.[18,19] Duarte et al reviewed in their study that additionally, PEEK crowns can be veneered with aesthetic materials for enhanced visual appeal. However, bonding PEEK to dental cements can be challenging, which may pose certain limitations in its application. Despite this, PEEK is particularly suitable for various prostheses in paediatric dentistry, where the

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need for durable, biocompatible materials is crucial. In addition to PEEK, other ceramic alternatives such as zirconia and lithium disilicate are commonly used in dental restorations. Zirconia is known for its high biocompatibility and the strongest fracture strength among available materials, making it an excellent choice for long-term restorations.[20,21] Silva et al reviewed in their study that in contrast, while PEEK offers significant resilience and comfort, it generally has lower fracture resistance compared to zirconia. Both PEEK and ceramic materials benefit substantially from CAD/CAM technology, which ensures a precise fit and minimizes the risk of complications such as secondary caries. Leading brands like JUVORA and Dent Care PEEK supply high-quality PEEK materials, enabling dental professionals to take advantage of the advancements in CAD/CAM technology for improved patient outcomes and experiences.[22]

Conclusion

In the context of their research, the authors investigated the durability of crowns fabricated using Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) technology, focusing specifically on two materials: PEEK (Polyetheretherketone) and high-strength ceramic. Their findings revealed distinct performance characteristics between the two materials. High-strength ceramics, such as Zirconia, demonstrated superior fracture resistance and longevity, particularly in high-stress regions of the dental structure. In contrast, PEEK showcased an impressive ability to absorb stress, leading to reduced wear on opposing teeth and overall enhanced durability, especially in preventing catastrophic failures. The authors concluded that additional research is essential to further explore these differences and validate their findings in a broader context.

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