Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/1rjs3w05

EVALUATION OF ADAPTATION AND WEAR SIMULATION OF INNOVATIVE TOOTH-COLORED PRIMARY POSTERIOR CROWNS

Mahmoud El-Said Ahmed Abd El-Aziz[1*], Mohamed Aboelkasme Wakwak[2], Yousef Hamed Abokhlifa[3], Alaa Nabil Abbas[4], Salam Mohamed EL Araby[5], Abdelhamid Abuelyazid Eissa[6], Mohamed Galal Aboelsoud[7], Ashraf Marawan El Azzazy[8], Waled Omar Ameen Kadour[9], Alaa N. Syam[10]

[1*]Lecturer of Dental Biomaterials, Faculty of Dental Medicine (Assiut), Al-Azhar University, Assiut, Egypt. E-mail: mahmoudabdelziz.46@azhar.edu.eg
[2]lecturer of pedodontics and oral health, Faculty of Dental Medicine (Assiut), Al-Azhar University, Assiut, Egypt.
[3]Assistant Professor of Paediatrics Dentistry and Dental Public Health, Faculty of Dental Medicine Al-Azhar University, Cairo, Egypt. E-mail: Yaa556464210@gmail.com
[4]Lecturer of Pedodontics and Oral Health Department Faculty of Dental medicine (Cairo -Boys) Al-Azhar University, Egypt. E-mail: alaaelshmmawy@gmail.com
[5]Lecturer of Pedodontics and Oral Health department, Faculty of Dental Medicine Girls branch AL -Azhar University, Egypt. E-mail: drpeace33@gmail.com
[6]Lecturer of pedodontics and public health department faculty of dental medicine Al-Azhar University, Egypt. Email: Abdelhamideissa666@gmail.com
[7]Lecturer of pedodontics and public health department faculty of dental medicine Al-Azhar university, Egypt. Email: MohamedAbouelSaud.209@azhar.edu.eg
[8]Lecturer, Department of Dental Biomaterial, Faculty of Dental Medicine, Assiut, Al- Azhar University, Egypt. E-mail: drashrafmarawan@gmail.com
[9]Lecturer of pedodontics and public health department faculty of dental medicine Al-Azhar university, Egypt. Email: dr.Waled.omar@gmail
[10]Assistant Professor of Dental Biomaterial, Faculty of Dental Medicine, Assiut, Al- Azhar University, Egypt. E-mail: alaasyam@yahoo.com

***Corresponding Author:** Mahmoud El-Said Ahmed Abd El-Aziz
*Lecturer of Dental Biomaterials, Faculty of Dental Medicine (Assiut), Al-Azhar University, Assiut, Egypt. E-mail: mahmoudabdelziz.46@azhar.edu.eg

Abstract

Purpose: The aim of this study was to evaluate the adaptation and wear simulation of innovative tooth-colored primary posterior crowns, specifically comparing ceramic (Zirconia) crowns and glass-reinforced fiber composite (FRC) crowns.

Material and methods: Fourteen posterior crowns from two manufacturers were used: Elephant Plus Zirconia crowns (Ceramic) and Figaro Glass-reinforced fiber composite crowns (FRC). Crowns were cemented to their respective master dies and the vertical marginal gaps were measured using a digital microscope and analyzed with Image J software. A wear simulation was performed utilizing a programmable logic controlled four-station multimodal ROBOTA chewing simulator, which included a thermocyclic protocol , simulating 3 months of clinical chewing conditions. Surface roughness was measured using optical profilometry and analyzed with WSxM software.

Results: The FRC group showed a significantly greater vertical marginal gap mean score (69.36 ± 8.84 µm) compared to the Ceramic group (26.44 ± 7.05 µm) ($p < 0.0001$). Surface roughness results indicated no significant difference between the groups before wear simulation, with the Ceramic group at 0.2496 ± 0.03 µm and the FRC group at 0.2395 ± 0.22 µm (P=0.494). After wear simulation, the roughness remained statistically non-significant between the Ceramic group (0.2609 ± 0.025 µm) and the FRC group (0.2533 ± 0.023 µm) (P=0.5667).

Conclusion: Ceramic crowns demonstrated superior marginal adaptation compared to FRC crowns, making them a preferable choice for scenarios requiring high precision. However, both materials exhibited similar wear resistance and surface roughness characteristics, indicating their viability for long-term restorative solutions in pediatric dentistry. Further research with larger sample sizes and long-term clinical trials is recommended to validate these findings.

INTRODUCTION

The field of dentistry has indeed seen significant advancements, especially in aesthetic dentistry. Researchers and physicians are increasingly focused on delivering naturally colored, long-lasting restorations to meet societal demands. This trend towards aesthetic treatments is beneficial for children as well, providing them with a sense of health and self-confidence. (1) Since 1950, stainless steel crowns (SSCs) have been utilized as a therapeutic option for restoring badly damaged primary teeth. Their ease of use and mechanical qualities have made them a reliable choice in pediatric dentistry. (2)

The outcome of dental therapy depends not only on the success of the restoration but also on factors such as aesthetic acceptance. This can be a significant concern for parents regarding their children's oral health. (3) A survey found that eighty-seven percent of parents are concerned about the aesthetics of their child's posterior tooth restorations. This highlights the importance of aesthetic considerations in pediatric dentistry to ensure both functional and visually pleasing results.(4)

Maintaining the aesthetics of primary teeth has posed a significant challenge for pediatric dentists. However, the desires of parents for more visually pleasing solutions have driven the development of better aesthetic options. (5) The desire for aesthetically pleasing smiles is on the rise among both adults and children. The appearance of a child is often linked to their quality of life, social acceptance, and psychological and physical growth. As a result, achieving a balance between functional and aesthetic dental restorations is essential for the overall well-being of young patients. (6)

Today, there are numerous options available in pediatric dentistry to address cosmetic issues, including tooth color-matched filling materials, pre-veneered stainless steel crowns (SSCs) and prefabricated crowns. These advancements provide more aesthetically pleasing solutions, ensuring that restorations not only restore function but also enhance the appearance of children's teeth. (7)

Direct composites are a popular option in pediatric dentistry for addressing cosmetic issues. Their chief benefits include excellent aesthetic value and the ability to keep the prepared tooth largely intact. However, direct composites can present challenges such as postoperative sensitivity and marginal microleakage. Additionally, for posterior primary molars with multiple severe cavities, direct composites may not be the best choice. In such cases, indirect composites and fiber-reinforced composites (FRCs) are often used as alternatives due to their superior durability and reduced risk of complications. (8)

Fiber-reinforced composite (FRC) is an additional technique used to improve the quality of composite restorations. This material consists of two components: the matrix, which establishes the setting for the procedure, and the fiber, which acts as the reinforcing element, providing strength and support. The combination of these components enhances the overall durability and performance of the restoration, making FRC a valuable option in pediatric dentistry for both aesthetic and functional outcomes. (9)

Recently, zirconia crowns have been employed for treating primary teeth, providing durability and aesthetic benefits. Prefabricated zirconia crowns represent a promising option for restoring primary teeth that have substantial structural damage, blending the mechanical strength of stainless steel crowns with enhanced aesthetic results. These crowns provide a strong, long-lasting solution while maintaining a natural tooth appearance, making them an excellent choice for restoring badly damaged primary teeth. [10]

Thus, pediatric dentists must have comprehensive knowledge about zirconia and fiber-reinforced composite crowns to effectively use them as alternatives to stainless steel crowns. Therefore, this study aims to further evaluate these types of crowns to facilitate their use and ensure optimal outcomes in pediatric dental restorations.

MATERIAL AND METHODS

Sample preparations:

In this study, fourteen posterior crowns from two manufacturers were used: Elephant Plus zirconia crowns (ceramic crowns from China) and glass-reinforced fiber composite crowns (FRC) (Figaro crowns from Minnesota, USA). The preparation for ceramic crowns required more refinement due to their rigidity, whereas FRC crowns could adapt to minor convex surfaces. Each crown was cemented onto its corresponding master die with finger pressure until fully seated, and then maintained under a 5-kg axial load for ten minutes in a seating pressure device.

Measurement of the marginal gap distance: A USB digital microscope with an inbuilt camera was used to take pictures of every specimen. The setup included a U500x Digital Microscope from Guangdong, China, featuring a 3-megapixel resolution camera positioned 2.5 cm vertically above the samples. The camera lens and illumination sources were set at approximately 90 degrees apart. Illumination was provided by 8 adjustable LED lamps with a high color index of 95%.

Images were taken at the highest resolution of 1280 × 1024 pixels and transferred to a linked personal computer. A consistent magnification of 40X was applied throughout the imaging process. The digital image analysis was conducted using Image J 1.43U software from the National Institute of Health, USA. All measurements in Image J, including gap widths, were initially recorded in pixels and subsequently calibrated using a reference object (a ruler in this case) to convert measurements into real-world units.

Photographs of the specimen margins were taken, and morphometric measurements were conducted at three equidistant landmarks along each surface. Each measurement point was assessed three times for accuracy. The collected data were compiled into tables for subsequent statistical analysis.

Wear simulation procedure

The two-body wear test was conducted using a newly developed four-station multimodal ROBOTA chewing simulator, controlled by programmable logic. This device features a thermo-cyclic protocol and is powered by a servo-motor (Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., Germany). It can concurrently simulate vertical and horizontal motions under regulated thermodynamical conditions. Every one of the four chambers in the simulator has an upper Jakob's chuck that securely holds the tooth antagonist utilizing a screw mechanism. The lower specimen container in each chamber embeds the specimen for testing. (Figure 1).

The specimens were positioned inside metal housings within the lower specimen container, with a 5 kg weight applied. The test was conducted 37,500 times to replicate three months of clinical chewing, according to previous studies. (Table 1).[11]

Table (1): Were test parameters

Wear test parameters	
Cold/hot bath temperature: 5℃/55℃	Dwell time: 60 s
Vertical movement: 1 mm	Horizontal movement: 3 mm
Rising speed: 90 mm/s	Forward speed: 90 mm/s
Descending speed: 40 mm/s	Backward speed: 40 mm/s
Cycle frequency 1.6 Hz	Weight per sample: from 3 kg
Torque; 2.4 N.m	

Figure(1) Chewing simulator utilized for wear test

Roughness assessment was used for measuring the wear.

Roughness methodology:

Optical profilometry meets the requirement for quantitatively analyzing surface topography without physical contact.(12) The wear of both the specimens and their counterparts was quantitatively assessed utilizing a 3D surface analyzer system prior and following loading. The samples were shot using a camera-equipped USB digital microscope (Scope Capture Digital Microscope, Guangdong, China), which was fixedly magnified by 120X and linked to a PC. A resolution of 1280 × 1024 pixels was used for each image capture.

To ensure consistency in roughness assessment, the digital microscope pictures were standardized by cropping them utilizing Microsoft Office Picture Manager, to 350 x 400 pixels. This specific area was chosen based on the typical dimensions of microorganisms anticipated to attach to the restoration surfaces in clinical setting. (13)

The resized pictures underwent analysis utilizing WSxM software (Version 5 develop 4.1, Nanotec, Electronica, SL).(14) In WSxM software, measurements such as boundaries, dimensions, frames, and parameters were initially documented in pixels. To translate these pixel-based measurements into precise real-world units, the system underwent calibration. This calibration process involved comparing a known-sized object (specifically, a ruler within the current research) against a scale produced within the program itself. WSxM software was utilized to compute the mean height (Ra) in micrometers (µm), serving as a dependable indicator of surface roughness. (15)

Subsequently, A 3D surface profile image of the samples was created utilizing digital image analysis software (Image J 1.43U, National Institute of Health, USA). The initial surface before wear was utilized as the reference point. Such technique enabled the generation of a three-dimensional representation showing the geometric alterations on the worn surface.

Results

Continuous variables were described using the mean and standard deviation. Before making comparisons, the study checked for homogeneity of variance and confirmed the normality of error distributions. Paired data were analyzed using the Student t-test. With a sample size of (n=7), the study had 80% power to detect large effect sizes in both main effects and pairwise comparisons at a 95% confidence level. Statistical analyses were performed utilizing Graph Pad Instat software for Windows (Graph Pad, Inc.). A p-value of less than 0.05 was deemed statistically significant.

Vertical marginal gap (µm):

Table 2 summarizes descriptive statistics for the vertical marginal gap (µm) across both groups, including the mean, standard deviation (SD), and 95% confidence intervals (CI) (low and high) and illustrated in Figures 2 and 3. The FRC group exhibited a significantly higher mean vertical marginal gap (69.36 ± 8.84 µm) compared to the Ceramic group (26.44 ± 7.05 µm), as confirmed by the Student t-test ($p < 0.0001 < 0.05$).

Table (2) Comparison of *vertical marginal* gap outcomes (Mean values± SDs) as function of material group

Variable		***Vertical marginal gap***		
		Mean ± SD	***95% CI***	
			Low	***High***
Material	***Ceramic***	26.44 ± 7.05	19.92	32.95
	FRC	69.36 ± 8.84	61.19	77.54
Statistics	***P value***	<0.0001*		

*; significant (p<0.05)

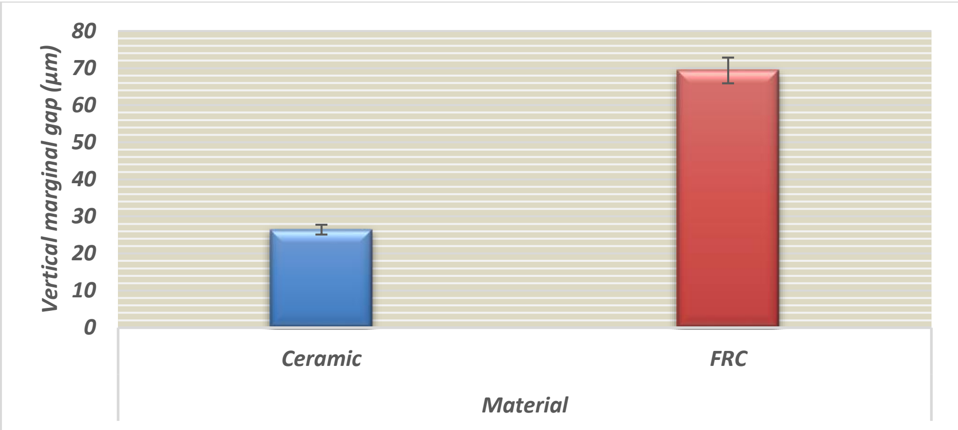


Figure (2) Column chart comparing total *vertical marginal* gap mean values as function of material group

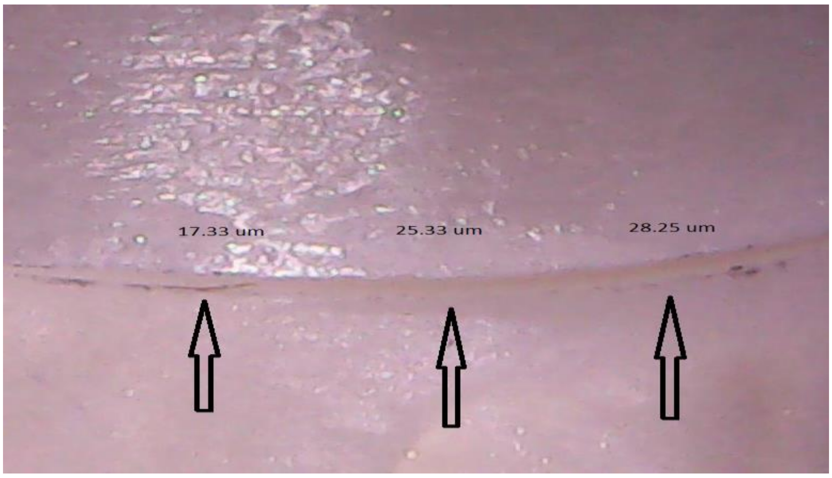


Figure (3) Representative digital microscopic image showing three equidistant measurement points for gap evaluation (X40)

Roughness change

The roughness results, measured as the roughness average (Ra) in micrometers (µm), include the mean, standard deviation (SD), and 95% confidence intervals (low and high) for both groups at different measurement sites on the tooth. These results are presented in Table 3 and illustrated in Figure 4.

Before the wear simulation, the Ceramic group had a slightly higher mean roughness value (0.2496 ± 0.03 µm) compared to the FRC group (0.2395 ± 0.22 µm). The unpaired t-test, nevertheless, indicated that the variation wasn't statistically significant (P = 0.494 > 0.05), as presented in Table 3 and Figure 4.

After the wear simulation, the Ceramic group again exhibited a slightly higher mean roughness value (0.2609 ± 0.025 µm) compared to the FRC group (0.2533 ± 0.023 µm). This difference also lacked statistical significance, according to the unpaired t-test (P = 0.5667 > 0.05), as presented in Table 3 and Figure 4.
For the Ceramic group, the mean roughness value after the wear simulation (0.2609 ± 0.025 µm) was slightly higher than before (0.2496 ± 0.03 µm). However, this increase wasn't statistically significant according to the paired t-test (P = 0.456 > 0.05), with a roughness change of 0.0113 µm, as presented in Table 3 and Figure 4.
Similarly, for the FRC group, the mean roughness value after the wear simulation (0.2533 ± 0.023 µm) was slightly higher than before (0.2395 ± 0.22 µm). This alteration was also not statistically significant according to the paired t-test (P = 0.2783 > 0.05), with a roughness change of 0.0137 µm, as illustrated in Table 3 and Figure 4.

Table (3) Roughness results (Mean values ±SDs) for both groups before and after wear simulation

Variables		***Before wear simulation***			***After wear simulation***			
		Mean± SD	***95% CI***		***Mean± SD***	***95% CI***		***Statistics***
			Low	***High***		***Low***	***High***	***P value***
Material	***Ceramic***	***0.2496±0.03***	0.219	0.278	***0.2609±0.025***	0.235	0.284	***0.456 ns***
	FRC	***0.2395±0.22***	0.217	0.260	***0.2533±0.023***	0.23	0.275	***0.2783 ns***
Statistics	***P value***	***0.494 ns***			***0.5667 ns***			

ns; non-significant (p>0.05)

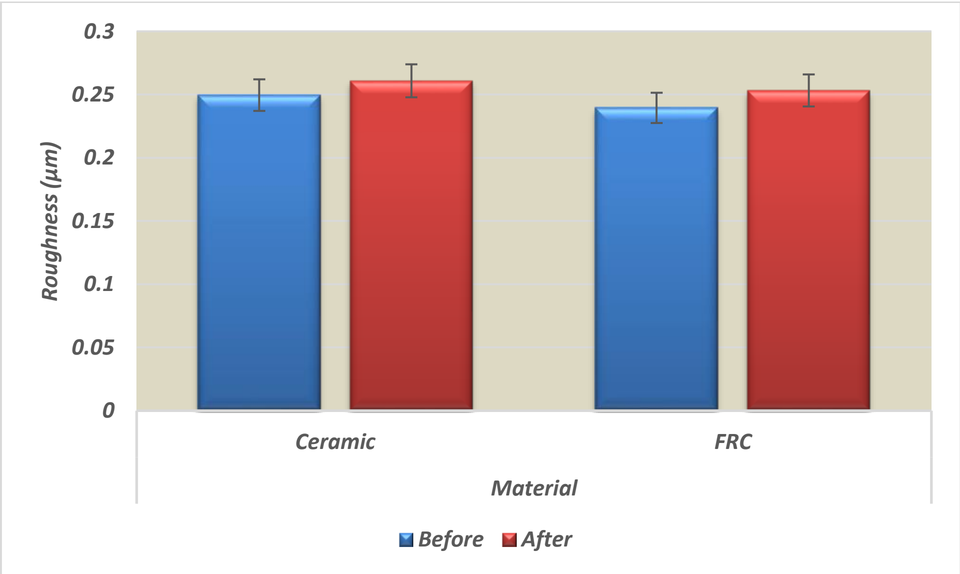
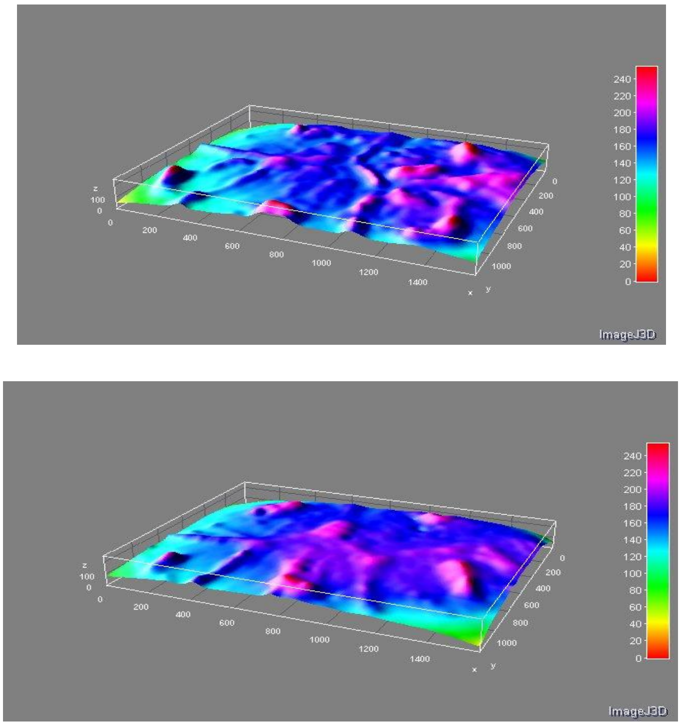
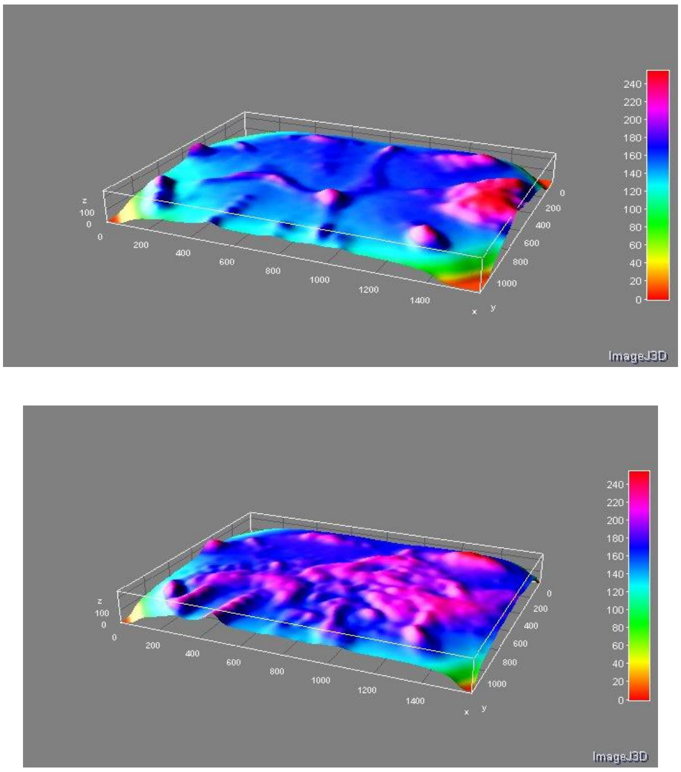


Figure (4) Column chart comparing roughness average means values between groups prior to and following wear simulation



Figure(5) A 3D representative image of the experimental samples before and after the wear simulation, showing the wear scars on ceramic crowns.



Figure(6) A 3D representative image of the experimental samples before and after wear simulation, illustrating the wear scar on Fiber Reinforced Composite (FRC).

Discussion:

This study compared the vertical marginal gap between two materials: Ceramic and Fiber-Reinforced Composite (FRC). The results revealed a statistically significant difference in the vertical marginal gap between the two groups. The FRC group had a significantly higher mean vertical marginal gap (69.36 ± 8.84 µm) compared to the Ceramic group (26.44 ± 7.05 µm), with a p-value of < 0.0001. This significant difference indicates that the choice of material significantly affects the marginal fit of restorations. A larger vertical marginal gap can potentially lead to increased plaque accumulation, secondary caries, and periodontal issues, which underscores the importance of material selection in clinical practice.(16)

Our findings align with previous studies that have highlighted the superior marginal adaptation of ceramic materials over composite resins. Ceramics are known for their stability and resistance to deformation, which may contribute to their better performance in maintaining a smaller marginal gap. For instance, study by Conrad emphasized the stability and minimal deformation of ceramic materials, which support their superior marginal fit .(17)

On the other hand, the higher marginal gap in the FRC group could be attributed to the inherent properties of composite materials, such as polymerization shrinkage and potential for micro-movement under loading. Study by Boitelle reported similar findings, noting that polymerization shrinkage in composite materials can result in larger marginal gaps .(18)

The roughness results before and after wear simulation showed non-significant variations amongst the Ceramic and FRC groups. Initially, the Ceramic group exhibited a slightly higher mean roughness value (0.2496 ± 0.03 µm) compared to the FRC group (0.2395 ± 0.22 µm), nonetheless, such difference wasn't statistical significance (P = 0.494). Similarly, after the wear simulation, the Ceramic group showed a non-significant higher mean roughness (0.2609 ± 0.025 µm) compared to the FRC group (0.2533 ± 0.023 µm), with a P-value of 0.5667. These findings suggest that both materials exhibited similar surface roughness characteristics under the conditions tested.(16)

The lack of significant roughness change post-wear simulation indicates that both materials possess adequate wear resistance, maintaining their surface integrity over time. This is particularly important for the longevity of dental restorations, as surface roughness can influence plaque accumulation and the overall aesthetic outcome. Study by Hamza reported that both ceramic and composite materials show minimal roughness changes after wear simulation, supporting our findings that both materials can maintain surface integrity over time. Furthermore, the slight increase in roughness for both groups after wear simulation, although not significant, could be attributed to the natural wear process and interaction with opposing dentition or materials.(19)

Clinical Implications

The clinical implications of these findings are multifaceted. Firstly, the significantly larger vertical marginal gap associated with FRC suggests that clinicians should exercise caution when selecting this material for restorations where marginal integrity is critical. The superior marginal fit of ceramic materials makes them a preferable choice in scenarios where precision is paramount. However, FRC materials still offer advantages such as ease of handling and potential cost benefits, which might be suitable for specific cases or patient preferences. Another study highlighted the importance of material selection based on clinical requirements, suggesting that while ceramics offer better marginal fit, FRC can be advantageous in terms of handling and cost .(20)

Secondly, the comparable surface roughness prior to and following wear simulation for both materials indicates that either can be used without significant concern for increased plaque retention or compromised aesthetics due to surface degradation. This makes both materials viable options for long-term restorative solutions, provided that their other properties align with the clinical requirements. Another study found that both ceramic and composite materials show similar wear resistance and surface roughness, reinforcing the viability of both materials for long-term use .(21)

Limitations and Future Research

The limited sample size of the study (n=7) might restrict the applicability of the results. Conducting future research with larger sample sizes and broader conditions could yield more reliable data. Additionally, long-term clinical trials would be beneficial to assess the performance of these materials over extended periods and under varying oral conditions. The in vitro nature of the wear simulation may not perfectly replicate the complex dynamics of the oral environment, suggesting the need for more sophisticated simulation techniques or in vivo studies to validate the current findings. Study by Heintze emphasized the importance of larger sample sizes and long-term studies to better understand material performance in clinical settings .(22)

Conclusion

In conclusion, the study provides valuable insights into the performance of ceramic and FRC materials can be evaluated by examining their vertical marginal gap and surface roughness. While Ceramic materials demonstrate superior marginal fit, both materials exhibit similar wear resistance and surface roughness characteristics. These findings can inform clinical decision-making, helping practitioners choose the appropriate material based on the specific requirements of each case. Additional research is necessary to build on these findings and investigate the long-term consequences of material selection in dental restorations.

References:

1. Babaji, P., et al. "Different crowns used in pediatric dentistry." Crowns in Pediatric Dentistry, first ed., Jaypee The Health Sciences Publisher, India (2016): 21-124.
2. Choi, Jae-Won, et al. "Wear of primary teeth caused by opposed all-ceramic or stainless-steel crowns." The journal of advanced prosthodontics 8.1 (2016): 43-52.
3. Salami, Anas, T. Walia, and R. Bashiri. "Comparison of parental satisfaction with three tooth-colored full-coronal restorations in primary maxillary incisors." Journal of Clinical Pediatric Dentistry 39.5 (2015): 423-428.
4. Holsinger, Daniel M., et al. "Clinical evaluation and parental satisfaction with pediatric zirconia anterior crowns." *Pediatric dentistry* 38.3 (2016): 192-197.
5. Hamrah, Mohammad Hassan, et al. "Evaluation of the Clinical, Child, and Parental Satisfaction with Zirconia Crowns in Maxillary Primary Incisors: A Systematic Review." International journal of dentistry 2021 (2021): 1-6.
6. Yıldırım, S., and Y. Ş. Uslu. "Effects of different pediatric drugs and toothbrushing on color change of restorative materials used in pediatric dentistry." Nigerian Journal of Clinical Practice 23.5 (2020): 610-618.
7. Chen, X. X., et al. "Clinical performance of rensin-bonded composite strip crowns in primary incisors." Beijing da xue xue bao. Yi xue ban= Journal of Peking University. Health sciences 52.5 (2020): 907-912.
8. Mohammadzadeh Z, Parisay I, Mehrabkhani M, Madani AS, Mazhari F. Clinical evaluation of fiber-reinforced composite crowns in pulp-treated primary molars: 12-month results. European Journal of Dentistry. 2016 Oct;10(04):522-8.
9. Freilich M, Meiers J, Duncan J, Goldberg A. Fiber-reinforced Composites in Clinical Dentistry. Chicago: Quintessence; 2000 Jan.
10. Garoushi S, Vallittu PK, Lassila LV. Fracture resistance of short, randomly oriented, glass fiber-reinforced composite premolar crowns. Acta biomaterialia. 2007 Sep 1;3(5):779-84.
11. Nawafleh, Noor, et al. "Lithium disilicate restorations fatigue testing parameters: a systematic review." *Journal of Prosthodontics* 25.2 (2016): 116-126.
12. Abouelatta OB. 3D surface roughness measurement using a light sectioning vision system. InProceedings of the world congress on engineering 2010 Jun 30 (Vol. 1, pp. 698-703).
13. Giacomelli L, Derchi G, Frustaci A, Bruno O, Covani U, Barone A, De Santis D, Chiappelli F. Surface roughness of commercial composites after different polishing protocols: an analysis with atomic force microscopy. The open dentistry journal. 2010;4:191.
14. Horcas I, Fernández R, Gomez-Rodriguez JM, Colchero JW, Gómez-Herrero JW, Baro AM. WSXM: A software for scanning probe microscopy and a tool for nanotechnology. Review of scientific instruments. 2007 Jan 1;78(1).
15. Kakaboura A, Fragouli M, Rahiotis C, Silikas N. Evaluation of surface characteristics of dental composites using profilometry, scanning electron, atomic force microscopy and gloss-meter. Journal of Materials Science: Materials in Medicine. 2007 Jan;18:155-63.
16. Fráter, Márk, et al. "Fracture resistance and marginal gap formation of post-core restorations: influence of different fiber-reinforced composites." *Clinical Oral Investigations* 24 (2020): 265-276.

17. Conrad, H. J., Seong, W. J., & Pesun, I. J. (2007). Current ceramic materials and systems with clinical recommendations: A systematic review. *The Journal of Prosthetic Dentistry*, 98(5), 389-404.
18. Boitelle, P., Mawussi, B., Tapie, L., & Fromentin, O. (2014). A systematic review of CAD/CAM fit restoration evaluations. *The Journal of Oral Rehabilitation*, 41(11), 853-874.
19. Hamza, T. A., & Ezzat, H. A. (2014). Effect of artificial accelerated aging on surface roughness and color stability of different ceramic restorations. *Stomatological Disciplinary*, 36(3), 168-177.
20. Al-Rabab'ah, M. A., Hammad, M. M., & Ibrahim, N. S. (2012). The effect of using two fiber post types on the marginal adaptation of CAD/CAM all-ceramic crowns. *Journal of Prosthodontic Research*, 56(1), 33-38.
21. Karakoca Nemli, S., Karakoca, S., Bayindir, F., & Yarici, S. (2013). Surface roughness of different resin-based composites after different finishing and polishing procedures. *Journal of Applied Oral Science*, 21(4), 358-364.
22. Heintze, S. D., & Rousson, V. (2012). Surface roughness of dental materials using different finishing/polishing procedures: A meta-analysis. *Dental Materials*, 28(5), 432-444.