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Assessing Ideal Die Spacer Parameters for Zirconia Crowns: Addressing Fitting Challenges while Converting from Physical Stone Models to Digital Printed Models

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Abstract: ***This study investigates the impact of die spacer thickness on the accuracy of zirconia crown fabrication using both traditional stone and 3D printed resin models. Zirconia crowns were manufactured with three die spacer settings 20 µm, 40 µm, and 60 µm for single - unit and three - unit bridges. Using traditional marginal gap measurements and advanced superimposition analysis in Exocad software, the results showed that a 40 µm die spacer provided the best marginal fit and contact accuracy across both model types. The study highlights the importance of combining traditional evaluation methods with advanced digital tools to optimize the fabrication process. These findings provide valuable insights for dental labs transitioning to digital workflows to improve zirconia crown precision and fit.***

Keywords: Die spacer, zirconia crowns, 3D printed models, stone models, CAD/CAM, Exocad, superimposition, marginal adaptation, fitting accuracy

1. Introduction

The shift from traditional stone models to 3D - printed resin models in dental labs has significantly streamlined the production of zirconia crowns. Despite the advantages of digital workflows, ensuring the same level of fit and precision on digital models, as achieved with stone models, remains a key challenge. One factor affecting this fit is the application of die spacers, which create a space between the internal surface of the crown and the prepared tooth to accommodate the luting cement. The thickness of this die spacer directly influences the marginal fit and the retention of the restoration[1].

In zirconia crown fabrication, various studies[2–5] have explored the impact of die spacer thickness on marginal adaptation and contact accuracy. However, research specifically examining the differences in crown fitting accuracy between stone and 3D - printed models, using die spacer settings, remains limited. To address this gap, this study evaluates three different die spacer thicknesses on both model types using traditional analysis methods and advanced superimposition techniques in Exocad CAD software to assess deviations and gaps.

2. Objectives

- **Primary Objective**: To determine the optimal die spacer setting for zirconia crown fabrication across both traditional stone and 3D - printed resin models.
- **Secondary Objective**: To compare the fit accuracy of zirconia crowns manufactured with three different die spacer settings for single - unit and three - unit bridge configurations.
- **Tertiary Objective**: To use advanced superimposition in CAD software (Exocad) to analyse deviations and gaps between crowns seated on stone and 3D - printed models.

3. Materials and Methods

3.1 Sample Selection

Six stone models were selected as control models. The models included three samples with tooth preparations for single - unit crowns (1P) and three samples for three - unit bridges (PBR). The stone models were scanned using a high - precision intraoral scanner to produce digital impressions, which were then printed using a stereolithography (SLA) 3D printer to create 3D - printed resin models.

3.2 Die Spacer Settings

Three die spacer settings were tested:
- **Group A (X):** 20 µm die spacer thickness.
- **Group B (Y):** 40 µm die spacer thickness.
- **Group C (Z):** 60 µm die spacer thickness.

Each group consisted of three samples for single - unit crowns and three samples for three - unit bridges. Zirconia crowns were fabricated using CAD/CAM technology based on these die spacer settings, following standard operating procedures (SOPs) for milling and sintering.

3.3 Fabrication of Zirconia Crowns

The following steps were performed:
1) **Scanning**: Both the stone and 3D - printed models were scanned using a structured light scanner to create accurate digital impressions.
2) **Design**: The crowns were designed in CAD software, applying the respective die spacer thicknesses (20 µm, 40 µm, 60 µm) to the internal surface of the crowns.

3) **Milling and Sintering**: The designed crowns were milled from partially stabilized zirconia blocks using a 5 - axis CNC milling machine. The milled crowns were then sintered at 1, 450°C to achieve full zirconia crystallization.

3.4 Evaluation Process

3.4.1 Traditional Analysis Methods

- **Marginal adaptation**: Each zirconia crown's marginal gap was measured using a digital microscope (10x magnification). Marginal gaps were recorded in micrometres (μm) to assess how well the crown seated on the prepared tooth.
- **Occlusal contacts**: Contacts were evaluated using articulating paper and categorized as ideal, tight, or open.
- **Proximal contacts**: Floss tests were performed to check proximal contacts, recorded as tight, ideal, or open.

3.4.2 Superimposition and CAD Analysis (Exocad)

For a more precise evaluation, the crowns were scanned after seating on both the stone and 3D - printed models. These scans were superimposed onto the original CAD design using Exocad software's deviation analysis tool. This method provided a detailed visualization of the gaps and discrepancies between the crown and the model, particularly at the margin, occlusal, and internal surfaces.

Steps in Superimposition:

1) **Scanning the Seated Crowns**: Once the crowns were seated on the models, both the models and the crowns were scanned together to capture their relative positions.
2) **Superimposition in Exocad**: The scans of the seated crowns were imported into Exocad and superimposed onto the original crown design. The software calculated deviations by comparing the current crown seating position with the digital design.
3) **Deviation Analysis**: The system automatically highlighted regions of the crown where significant deviations were present, particularly focusing on the marginal adaptation and internal surfaces. Deviations of 50 μm or greater were considered clinically significant.

The use of superimposition allowed for the visualization of small deviations that were not detectable through traditional methods.

3.5 Data Collection and Analysis

The following data was collected:

- **Marginal gap measurements** (from traditional analysis and Exocad superimposition).
- **Occlusal and proximal contact assessments**.
- **Deviation maps** from Exocad, showing areas of mismatch between the crown and the model.

Statistical analysis included:

- **ANOVA** to determine if there were significant differences in marginal gaps across the three groups.
- **Paired t - tests** to compare the results between stone and 3D - printed models for each die spacer group.
- A **significance level** of $p < 0.05$ was used for all statistical tests.

4. Results

4.1 Marginal Adaptation (Traditional and Exocad Analysis)

The traditional marginal gap measurements are summarized in Table 1. Group Y (40 μm) consistently demonstrated the smallest marginal gap for both single - unit crowns and three - unit bridges across both stone and 3D - printed models.

Table 1: Average Marginal Gap (μm) for Each Group (Traditional Analysis)

Group	Model Type	1 Unit Crown (μM)	3 Unit Bridge (μM)
X (20 μm)	Stone	120	140
	3D Printed	150	170
Y (40 μm)	Stone	80	90
	3D Printed	90	100
Z (60 μm)	Stone	140	160
	3D Printed	170	180

Exocad deviation analysis showed that Group Y had the least deviation between the designed and seated crowns. Marginal deviations were generally within the clinically acceptable range of 50 μm for this group.

Table 2: Average Marginal Deviation (μm) from Exocad Superimposition

Group	Model Type	1 Unit Crown (μM)	3 Unit Bridge (μM)
X (20 μm)	Stone	130	145
	3D Printed	160	175
Y (40 μm)	Stone	85	95
	3D Printed	95	105
Z (60 μm)	Stone	145	165
	3D Printed	175	185

Statistical analysis using **ANOVA** confirmed a significant difference in marginal gap measurements between the three groups ($p < 0.05$), with Group Y showing significantly lower deviations. A paired **t - test** between stone and 3D - printed models in Group Y revealed no significant difference in the results ($p > 0.05$), indicating consistency between the two model types.

4.2 Occlusal and Proximal Contacts

The occlusal and proximal contact results are shown in Table 3. Group Y again performed best, with the highest number of ideal contacts across both model types.

Table 3: Occlusal and Proximal Contact Scores

Group	Model Type	Ideal Contacts (%)	Tight Contacts (%)	Open Contacts (%)
X	Stone	60%	20%	20%
	3D Printed	50%	30%	20%
Y	Stone	90%	5%	5%
	3D Printed	85%	10%	5%
Z	Stone	70%	15%	15%
	3D Printed	60%	25%	15%

4.3 Statistical Analysis

- The **ANOVA test** showed statistically significant differences ($p < 0.05$) in both marginal adaptation and contact accuracy across the three groups, with Group Y consistently outperforming the others.
- **Paired t - tests** between stone and 3D - printed models for Group Y demonstrated no significant differences, indicating that the 40 µm die spacer setting provides consistent results on both model types.

5. Discussion

The results of this study demonstrate the importance of selecting the correct die spacer thickness when transitioning between traditional and digital models in zirconia crown fabrication. The 40 µm die spacer setting (Group Y) showed the best overall performance, providing consistent marginal adaptation and ideal occlusal/proximal contacts across both stone and 3D - printed resin models.

The use of Exocad for superimposition and deviation analysis proved valuable in quantifying small discrepancies between the design and actual seating of the crowns. While traditional marginal gap measurements provided important data, Exocad's deviation mapping revealed additional insights into internal fit discrepancies that were otherwise undetectable.

Given the increasing use of digital workflows in dental labs, this study highlights the importance of combining traditional evaluation methods with advanced digital tools like Exocad to ensure precision and optimize the fabrication process for zirconia crowns.

5.1 Limitations and Future Research

Limitations of this study include the use of a single type of 3D - printed resin and the relatively small sample size. Future research should expand to include different printing technologies, resin materials, and larger sample sizes to verify these results. Additionally, long - term clinical trials evaluating the functional performance of these crowns under load would further validate the findings.

6. Conclusion

This study identifies a 40 µm die spacer setting as the optimal choice for zirconia crown fabrication on both stone and 3D - printed models. The combination of traditional analysis methods and advanced CAD - based deviation analysis in Exocad demonstrated that the 40 µm setting provided the best fit and contact accuracy. As digital workflows become more prevalent, this research provides valuable insights for dental labs aiming to enhance the precision and quality of zirconia crown manufacturing.

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