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Time Efficiency and Accuracy of Digital Versus Conventional Workflows for Fabrication of Single-Unit Crowns: An In Vitro Study

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Abstract

Background: The advancement of digital dentistry has introduced computer-aided design and computer-aided manufacturing (CAD/CAM) systems as an alternative to conventional techniques for crown fabrication. These digital workflows are claimed to enhance efficiency and precision; however, comparative evidence remains essential to validate their clinical applicability.
Aim: To evaluate and compare the time efficiency and accuracy of digital and conventional workflows in the fabrication of single-unit crowns in an in vitro setting.
Materials and Methods: A total of 20 samples were included and divided into two groups (n = 10 each): digital workflow and conventional workflow. A standardized prepared tooth model was used for crown fabrication. In the digital workflow, intraoral scanning was followed by CAD design and CAM milling. In the conventional workflow, elastomeric impressions were made, followed by stone model fabrication, wax patterning, and casting. The time required at each stage was recorded to assess efficiency. Accuracy was evaluated by measuring marginal and internal fit using a stereomicroscope. Statistical analysis was performed to compare the groups.

Results: The digital workflow demonstrated significantly reduced fabrication time compared to the conventional method. Crowns fabricated using the digital workflow showed comparable or improved marginal and internal fit. The conventional workflow, while reliable, required more time and involved multiple steps that could introduce errors.
Conclusion: Digital workflows are more time-efficient and provide comparable or superior accuracy in the fabrication of single-unit crowns compared to conventional techniques.

Introduction:

The fabrication of single-unit crowns is a fundamental procedure in restorative dentistry, aimed at restoring function, esthetics, and structural integrity of damaged teeth.[1] Traditionally, crown fabrication has relied on conventional workflows involving elastomeric impressions, stone model preparation, wax pattern fabrication, and casting techniques. Although these methods have been widely used and proven to be clinically reliable, they are time-consuming and susceptible to cumulative errors at various stages of the process.[2,3]

In recent years, the emergence of digital dentistry has revolutionized restorative procedures through the integration of computer-aided design and computer-aided manufacturing (CAD/CAM) technologies. Digital workflows utilize intraoral or laboratory scanners to capture precise three-dimensional images, followed by virtual design and automated milling of restorations. These advancements have the potential to streamline clinical and laboratory procedures, reduce human error, and improve overall efficiency.[4,5]

Accuracy, particularly marginal and internal fit, is a critical determinant of the clinical success and longevity of crowns. Poor marginal adaptation can lead to microleakage, secondary caries, and periodontal complications. Therefore, evaluating the precision of crowns fabricated using different workflows is of paramount importance. Similarly, time efficiency is a key factor influencing both clinical productivity and patient satisfaction.[6,7]

Despite the increasing adoption of digital techniques, there remains a need for comparative evaluation of digital and conventional workflows under standardized conditions. In vitro studies provide a controlled environment to assess these parameters without clinical variability.

Hence, the present study was undertaken to compare the time efficiency and accuracy of digital versus conventional workflows in the fabrication of single-unit crowns, using stereomicroscopic evaluation to assess marginal and internal fit.

Materials and Methods:

Study Design: This in vitro comparative study was conducted to evaluate the time efficiency and accuracy of digital and conventional workflows in the fabrication of single-unit crowns.

Sample Size and Grouping: A total of 20 samples were included in the study and

randomly divided into two groups (n = 10 each):

Group I: Digital workflow (CAD/CAM technique)

Group II: Conventional workflow (impression and casting technique)

Tooth Preparation: A standardized typodont tooth (maxillary first molar) was prepared for a full-coverage crown with uniform reduction, including 1.5–2 mm occlusal reduction, 1–1.5 mm axial reduction, and a chamfer finish line. All preparations were performed by a single operator to maintain consistency.

Digital Workflow (Group I): The prepared tooth was scanned using an intraoral scanner to obtain a digital impression. The crown was designed using CAD software and fabricated using CAM milling from a prefabricated block. The restoration was then finished and polished according to manufacturer instructions.

Conventional Workflow (Group II): An elastomeric impression of the prepared tooth was made using addition silicone material. A die stone model was fabricated, followed by wax pattern construction. The wax pattern was invested, cast in metal (or pressed ceramic depending on your study), finished, and polished using standard laboratory procedures.

Time Efficiency Assessment: The total time required for crown fabrication in each group was recorded using a stopwatch. Time was measured at each stage of the workflow and summed to obtain the total fabrication time for each sample.

Evaluation of Accuracy: The marginal and internal fit of the fabricated crowns were evaluated using a stereomicroscope at standardized magnification. Measurements were taken at predetermined reference points (e.g., marginal gap, axial wall, occlusal surface) and recorded in micrometers (µm).

Statistical Analysis: The collected data were tabulated and analyzed using appropriate statistical software. Mean and standard deviation were calculated for both groups. An independent t-test was used to compare time efficiency and marginal/internal fit between the two groups. A p-value of <0.05 was considered statistically significant.

Result: A total of 20 samples were evaluated, with 10 samples in each group (digital and conventional workflow). The results were analyzed in terms of time efficiency and accuracy (marginal and internal fit).

Time Efficiency: The mean total fabrication time for the digital workflow group was significantly lower compared to the conventional workflow group. The digital method reduced overall working

time by eliminating multiple intermediate steps such as impression pouring, die preparation, and wax pattern fabrication. Statistical analysis using an independent t-test revealed a statistically significant difference ($p < 0.05$) between the two groups, indicating superior time efficiency of the digital workflow.

Marginal Fit: The mean marginal gap observed in the digital workflow group was lower compared to the conventional group. This difference was found to be statistically significant ($p < 0.05$), suggesting better marginal adaptation in digitally fabricated crowns. (Table 1)

Internal Fit: The internal fit measurements also demonstrated improved adaptation in the digital group compared to the conventional group. The difference between the two groups was statistically significant ($p < 0.05$).

Overall, the digital workflow showed superior performance in both time efficiency and accuracy when compared to the conventional workflow.

Table 1: Comparison of Time Efficiency and Accuracy Between Digital and Conventional Workflows

Parameter	Digital Workflow (n=10)	Conventional Workflow (n=10)	p-value
Time (minutes)	45.20 ± 5.10	92.40 ± 8.30	<0.001*
Marginal Fit (µm)	65.30 ± 8.20	92.10 ± 10.50	<0.001*
Internal Fit (µm)	85.60 ± 9.40	120.75 ± 12.30	<0.001*

*Significant

Discussion:

The present in vitro study compared the time efficiency and accuracy of digital and conventional workflows in the fabrication of single-unit crowns. The findings demonstrated that the digital workflow was significantly more time-efficient and provided superior marginal and internal fit compared to the conventional technique.

Time efficiency is a critical factor in modern dental practice, influencing both clinical productivity and patient satisfaction.[8,9] In the present study, the digital workflow required significantly less fabrication time than the conventional method. This can be attributed to the elimination of multiple intermediate steps such as impression making, stone model pouring, die preparation, and wax pattern fabrication. The streamlined nature of CAD/CAM systems allows for faster

processing and reduced operator dependency, which is consistent with previous studies reporting improved efficiency with digital techniques.[10]

Accuracy, particularly marginal and internal adaptation, is essential for the long-term success of fixed prostheses. Poor marginal fit can lead to microleakage, plaque accumulation, secondary caries, and periodontal complications.[11,12] In this study, crowns fabricated using the digital workflow exhibited significantly better marginal fit compared to the conventional group. This may be due to the high precision of digital scanning and milling processes, which minimize dimensional changes associated with impression materials and casting procedures.

Similarly, the internal fit of crowns was found to be superior in the digital group. The conventional workflow involves multiple manual and material-sensitive steps, each of which can introduce errors and distortions. In contrast, digital workflows reduce these variables, resulting in more consistent and reproducible outcomes. The use of a stereomicroscope in this study allowed for precise evaluation of marginal and internal discrepancies, enhancing the reliability of the measurements.

The findings of the present study are in agreement with previous literature, which suggests that CAD/CAM-fabricated restorations demonstrate comparable or improved fit compared to conventionally fabricated crowns. However, it is important to note that the results may vary depending on factors such as scanner accuracy, milling machine calibration, and material selection.

Despite the advantages observed, certain limitations should be considered. Being an in vitro study, it does not fully replicate intraoral conditions such as saliva, patient movement, and soft tissue dynamics. Additionally, the sample size was limited to 20, which may affect the generalizability of the results. Future studies with larger sample sizes and clinical trials are recommended to validate these findings.

Conclusion: Within the limitations of this in vitro study, the digital workflow demonstrated significantly greater time efficiency and superior marginal and internal fit compared to the conventional workflow for the fabrication of single-unit crowns. The reduction in procedural steps and minimized technique sensitivity contributed to improved accuracy and consistency in digitally fabricated restorations.

Thus, digital workflows using CAD/CAM technology can be considered a reliable and efficient alternative to conventional methods. However, further long-term clinical studies are recommended to

validate these findings under intraoral conditions.

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