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ORIGINAL ARTICLE

# Digital evaluation of occlusal reduction of metal crown preparations in students in the COVID-19 era: A cross-sectional study



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## KEYWORDS

Crown;  
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Occlusal reduction

**Abstract** *Introduction:* Occlusion of extra-coronal restorations depends on the reduction achieved during crown preparation. Ensuring adequate reduction is therefore essential for the success of the final restoration. The objective of this study was to digitally quantify the occlusal reduction performed by preclinical undergraduate dental students and to compare their performance across the year and using a hybrid teaching approach developed because of the COVID-19 pandemic.

*Methods:* Eighty full metal crown preparations on typodonts were scanned using the KaVo Arc-tica 3D Optical scanner. Occlusal reduction was measured using Autodesk Fusion 360 v2.0 by superimposing an unprepared tooth over the preparation and taking measurements at six occlusal points (mesio-buccal (MB), disto-buccal (DB), mesio-lingual (ML), disto-lingual (DL), mesial fossa (MF), and distal fossa (DF)). A general linear model was used to compare student performance in the mid vs final year exams and in 2018/19 vs 2020/2021.

*Results:* The adequacy of occlusal reduction was variable. Occlusal reductions of the MF ( $p = 0.014$ ) and DF ( $p = 0.011$ ) were significantly lower in the final exam than the mid-year exam in 2018/2019. There was also occlusal under-reduction at all six occlusal points in 2020/2021 compared with 2018/2019.

*Conclusions:* Students must be encouraged to use verification guides throughout the procedure to ensure adequate reductions. These verification methods can be as simple as putty indices or as advanced as optical scanners. The use of verification methods alongside a hybrid virtual and live teaching approach may guarantee the best results.

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## 1. Introduction

Crown preparation is a basic dental procedure taught early in undergraduate training. Although full metal crowns are now used less frequently, they are still recommended in patients with parafunctional habits to manage tooth surface loss due to attri-

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tion, especially when combined with erosion (Rees and Somi 2018). Full metal crown preparation is the most conservative full extracoronary crown preparation, so undergraduates can find it challenging. Once a tooth is prepared for extracoronary restoration, the risk of root canal treatment increases (Saunders and Saunders 1998). Both under- and over-preparation can be problematic in terms of subsequent impression taking, crown fabrication, clinical occlusal verification, and cementation. Additionally, sufficient reduction is mandatory to ensure adequate crown thickness, strength, aesthetics, and contour (Seet et al., 2020). To reduce the risk of over-reduction, dentists must use the correct bur size and type, hold the hand-piece at the right angles, sit in the correct position, and be aware that the patient's position may need adjusting for better visualization (Rosenstiel et al., 2022). The use of reduction guides can also reduce unnecessary over-cutting of dental structures.

Certain guidelines must be followed while performing occlusal reduction: (i) achieving optimal occlusal reduction, which usually varies between non-functional and functional cusps, which require additional cutting (Rosenstiel et al., 2022); (ii) following occlusal morphology to avoid unnecessary under- or over-cutting of the tooth structure and/or endangering the pulp (Langeland and Langeland 1965); and (iii) avoiding irregularities or sharp line angles where stress might be concentrated.

Teaching methods changed due to COVID-19, with physical contact restricted in educational institutions and education mainly provided virtually. After that, many educational facilities used hybrid virtual and standard teaching methods, with some data suggesting that the hybrid approach delivers the best features of online and in-person learning (Tawfik et al., 2022). Hybrid teaching may therefore be a necessary change persisting from the pandemic, as virtual teaching can be used for theoretical teaching while saving time and resources for practical training. Moreover, virtual teaching may be useful in remote areas where mentors are not available or can be offered instead of pre-recorded online sessions.

Several studies have investigated preclinical and clinical student performance with respect to convergence angles (Patel et al., 2005, Marghalani 2014, Marghalani 2015) and undercuts (Marghalani 2016). Occlusal reduction has been examined in the clinical setting in final year dental students using digital caliper measurements on working dies (Al-Omari and Al-Wahadni 2004). Another study tested the effectiveness of intraoral scanning for assessing full metal crown preparation performed by dental students on a patient simulator (Seet et al., 2020), with digital assessment proving to be suboptimal to conventional assessment. However, there has yet to be a study quantifying occlusal reduction performed by undergraduate students in the preclinical setting.

This study therefore quantified, using 3D digital images, the occlusal reduction achieved by undergraduate dental students in the preclinical setting and compared outcomes across the academic year (at mid-year and final examinations) and using live and hybrid teaching, the latter enforced by the pandemic.

## 2. Materials and methods

The Research Ethics Committee of the Faculty of Dentistry at King Abdulaziz University Dental Hospital approved this retrospective study (KAUDH; Ref: 4429209). The inclusion crite-

ria were lower molars prepared for a full metal crown in fulfilment of preclinical mid- and final-year examination by fourth year undergraduate students attending King Abdulaziz University in the 2018/2019 and 2020/2021 academic years. Exclusion criteria were (i) prepared upper molars, premolars, or anterior teeth; and (ii) teeth prepared as requirements and minimal standards procedures throughout the academic year. In total, 80 full metal crown preparations were performed by fourth year students in the preclinical mid and final examinations on typodonts.

Crown preparations were scanned using the KaVo Arctica 3D optical scanner (Elexadent, London, UK) to quantify occlusal reduction (Fig. 1). Four groups were evaluated: group 1: 20 crown preparations for the 2018/2019 mid-year examination; group 2: 20 crown preparations for the 2018/2019 final year examination; group 3: 20 crown preparations for the 2020/2021 mid-year examination; and group 4: 20 crown preparations for the 2020/2021 final year examination. The sample was a convenience sample from the 2018/2019 and 2020/2021 academic year groups based on a similar study by Marghalani (2014).

An unprepared tooth was also scanned as the index tooth. STL files were imported into Autodesk Fusion 360 v2.0 (Autodesk Inc., USA), and occlusal reduction was measured at six points: mesio-buccal cusp (MB), disto-buccal cusp (DB), mesio-lingual cusp (ML), disto-lingual cusp (DL), mesial fossa (MF), and distal fossa (DF). An image of an unprepared tooth was superimposed on the prepared tooth and two points were placed on the unprepared cusp/fossa and on the prepared cusp/fossa. Occlusal reduction was then measured by a prosthodontic consultant by calculating the distances from unprepared cusps/fossae to prepared cusps/fossae at all six points of the same tooth. Occlusal reduction measurements were initially taken and then re-taken two weeks later by the same prosthodontist to examine intra-examiner reliability.

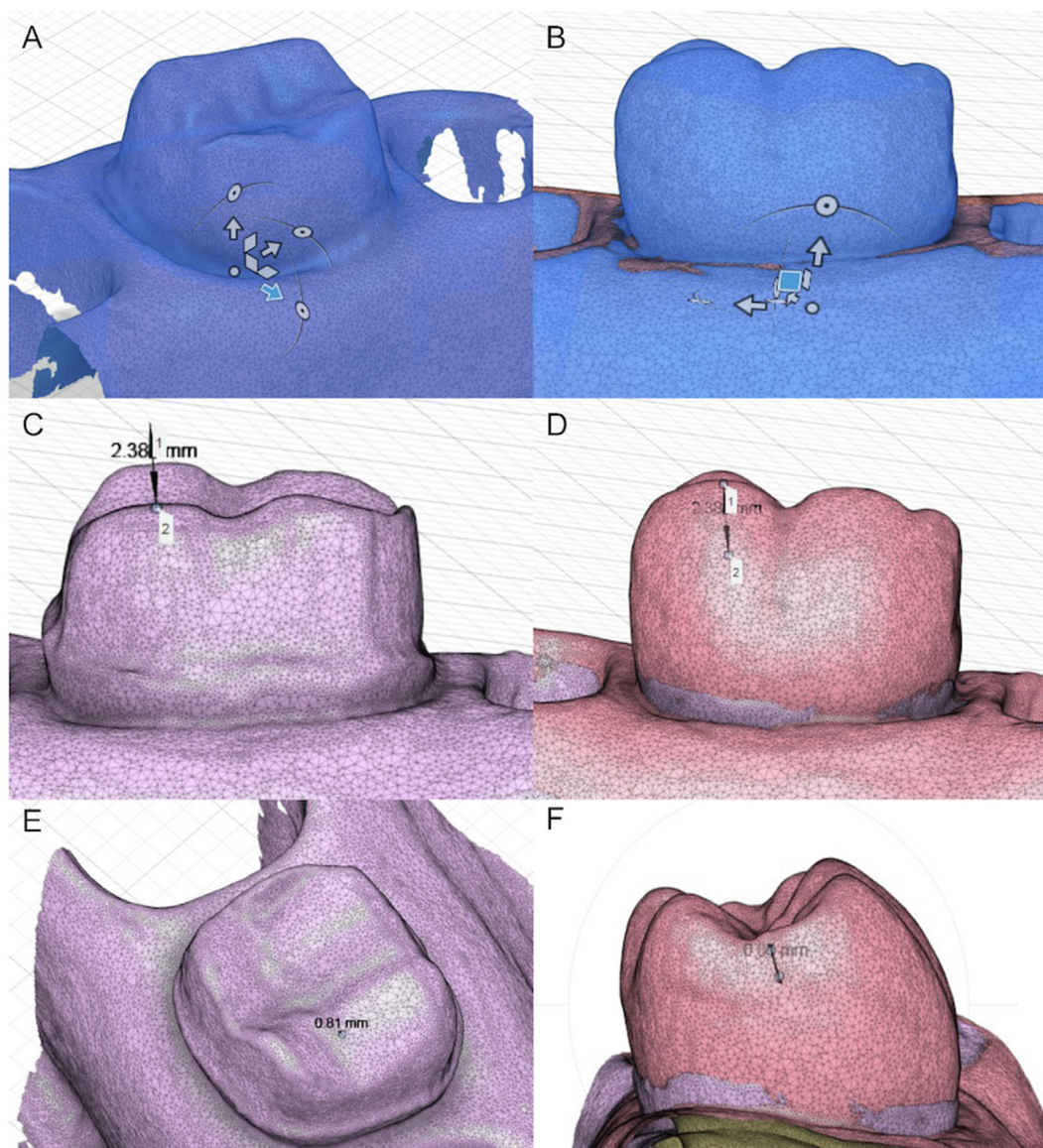
Criteria for adequacy of occlusal reduction were: a 1.5–2.0 mm reduction of the functional cusps (MB and DB) and a 1.0–1.5 mm reduction of the non-functional cusps (ML, DL) and MF and DF, as previously (Seet et al., 2020).

Data were imported into SPSS Statistics v28 (IBM SPSS Inc., Armonk, NY) and descriptive statistics (mean and standard deviation, SD) calculated. A multivariate general linear model was used to detect significant differences in mean student performance in the mid-term and final examinations and in academic year 2018/2019 vs 2020/2021. Interclass correlation coefficients (ICC) and their 95% confidence intervals (CIs) were calculated based on a single-measurement, absolute-agreement, two-way mixed-effects model.  $p < 0.05$  was considered statistically significant.

## 3. Results

### 3.1. Occlusal reduction performance

The adequacy of occlusal reduction was variable. The mean occlusal reduction in the functional cusps (MB and DB) fulfilled the required reduction of 1.5–2.0 mm in both semesters in 2018/2019 but not in 2020/2021, where it was under-reduced (Table 1). In 2018/2019, the mean occlusal reduction in DL was fulfilled, but the MF and DF were under-reduced (mean reductions 0.605 and 0.464, respectively) and the ML



**Fig. 1** (A) STL file imported into Autodesk Fusion 360 of prepared tooth. (B) Prepared tooth superimposed with a full contoured crown (unprepared). (C) Distance measured from point selected on the unprepared superimposed MB cusp to the point selected on the prepared MB cusp. (D) Same as in (C) with the unprepared tooth superimposed. (E) Distance measured from point selected on the unprepared superimposed MF to the point selected on the prepared MF with the unprepared tooth superimposed. (F) Same as in (E) with the unprepared tooth superimposed.

was over-reduced (mean 1.72 mm). In 2020/2021, there was occlusal under-reduction at most points except for ML and DL in 2020/2021, which just reached adequacy (Table 1).

### 3.2. Comparison between mid-year and final exams

There was a significant difference in the amount of occlusal reduction between the mid-year and final assessments for the MF ( $p = 0.014$ ) and DF ( $p = 0.011$ ) in 2018/2019 (Table 1). However, there were no significant differences in occlusal reduction between the first and second semesters at the other locations, nor were there any significant differences at any location in the 2020/2021 academic year. Most students used

putty indices as verification guides in the first semester but not in the second semester.

### 3.3. Comparison of student performance between academic years

There was significantly less occlusal reduction at all six locations in academic year 2020/2021 compared with in 2018/2019 (all  $p < 0.05$ ; Table 2).

### 3.4. Intra-examiner reliability of occlusal reduction assessment

Although variable, there was generally a positive correlation between the values recorded for the occlusal reduction mea-

**Table 1** Comparison of student performance between the mid and final year exams.

Academic year	Location	Occlusal reductions in both semesters (mm)	Occlusal reduction (mid-year exams) (mm)	Occlusal reduction (final year exams) (mm)	Pairwise comparison between mid- and final-year exams p-value
		Mean (SD)	Mean (SD)	Mean (SD)	
18/19	MB	1.68 (0.45)	1.70 (0.45)	1.66 (0.46)	0.757
	DB	1.49 (0.43)	1.55 (0.38)	1.43 (0.47)	0.343
	ML	1.72 (0.48)	1.70 (0.43)	1.74 (0.52)	0.792
	DL	1.40 (0.47)	1.47 (0.45)	1.34 (0.48)	0.362
	MF	0.61 (0.36)	0.73 (0.34)	0.48 (0.35)	<b>0.014</b>
	DF	0.46 (0.38)	0.58 (0.40)	0.34 (0.31)	<b>0.011</b>
20/21	MB	1.15 (0.39)	1.05 (0.39)	1.25 (0.38)	0.133
	DB	1.05 (0.35)	1.01 (0.36)	1.09 (0.34)	0.544
	ML	0.94 (0.43)	0.81 (0.37)	1.07 (0.46)	0.067
	DL	0.95 (0.38)	0.90 (0.37)	1.01 (0.39)	0.416
	MF	0.45 (0.29)	0.38 (0.23)	0.51 (0.34)	0.171
	DF	0.31 (0.20)	0.29 (0.22)	0.32 (0.20)	0.737

**Table 2** Comparison of student performance in academic year 18/19 vs 20/21.

Location	Academic Year 18/19 [Mean (SD)] (mm)	Academic Year 20/21 [Mean (SD)] (mm)	p-value
MB	1.68 (0.45)	1.15 (0.39)	< <b>0.001</b>
DB	1.49 (0.43)	1.05 (0.35)	< <b>0.001</b>
ML	1.72 (0.48)	0.94 (0.43)	< <b>0.001</b>
DL	1.40 (0.47)	0.95 (0.38)	< <b>0.001</b>
MF	0.61 (0.36)	0.45 (0.29)	<b>0.027</b>
DF	0.46 (0.38)	0.31 (0.20)	<b>0.019</b>

surements. The ICC ranged from 0.154 for the MF to 0.728 for the DL (see Table 3).

#### 4. Discussion

Here we explored the performance of fourth year undergraduate dental students in undertaking occlusal reduction for full metal crown preparation in fulfillment of their mid- and end of year examinations and compared outcomes within the same year and between academic years.

Occlusal reduction was variable at different time points. It is known that over-reduction affects the biological and mechanical outcomes of tooth preparations (Rosenstiel et al.,

2022). Unnecessary removal of more than the required amount of tooth can affect the pulp status if the tooth is vital, leading to either pulp exposure and unnecessary root canal treatment or pulp irritation and an increased risk of pulp necrosis. Conversely, over reducing a non-vital tooth will affect the mechanics by reducing the crown height and hence affecting retention of the extra-coronal restoration. Additionally, under-reduction in cases of full metal crown preparation will lead to insufficient space for the laboratory to construct the metal crown and over contouring to compensate for the lack of space and consequent occlusal dysfunction. It is therefore imperative that the dentist reduces the tooth within acceptable thresholds, which relies on teaching the correct skills.

Occlusal reduction was significantly different in the MF and DF between the first and second semesters in 2018/19 and varied significantly at all locations between 2018/19 and 2020/21. The decrease in occlusal reduction in the MF from 0.73 to 0.47 and in the DF from 0.58 to 0.34 in 2018/19 may have been due to increased student confidence and a reduction in the use of putty indices as the year progressed, as previously (Davey et al., 2015, Gilmour et al., 2016, Puryer et al., 2018). Although student confidence is an important educational outcome (Packer et al., 1999), confidence does not necessarily equate to competence (Puryer et al., 2018). Student confidence may have increased over the year due to the nearly acceptable performance in the mid-year exam (sufficient reduction at four locations) and almost sufficient performance in the MF and

**Table 3** Intra-examiner reliability of amount of occlusal reduction at the six different points.

	Interclass Correlation	95% Confidence Interval		
		Lower Bound	Upper Bound	Value
MB	0.655	0.088	0.902	4.798
DB	0.690	0.15	0.913	5.443
ML	0.336	-0.333	0.78	2.014
DL	0.728	0.224	0.925	6.345
MF	0.154	-0.493	0.692	1.365
DF	0.615	0.02	0.888	4.189

minimal in the DF. This is consistent with a previous study reporting that student confidence increases with successful performance (Stankov et al., 2014). Most students opted to not use putty indices in the second semester, perhaps due to increased confidence levels. However, the occlusal reduction in the MF and DF in both academic years was insufficient compared with the other locations. If no neighboring teeth were placed during preparation, the students might have assumed sufficient reduction in the MF and DF, especially if no reduction guides were used. Additionally, the dipped MF and DF morphology compared with cusps may be misinterpreted as successful reduction.

The decrease in mean occlusal reduction at all six locations from 2018/2019 to 2020/2021 was likely to have been due to the teaching approach. In 2018/2019, students received live demonstrations immediately after a standard lecture on the topic, albeit with a staff to student ratio of 1:10, which may not have guaranteed adequate visibility. In 2020/2021, due to COVID-19, students had to adapt to the extraordinary circumstances of the pandemic. Students were first given an online live lecture about the topic, where they could ask questions. Then, the night before the laboratory session, students were instructed to watch a video clip of the procedure. During the practical session, students performed the procedure while watching and replaying the video of the procedure at the same time. Those students who failed to understand the concept were given a 1:1 live demonstration with the assigned faculty member. Students were provided with feedback throughout the procedure at each step of tooth preparation. Correctable mistakes (e.g., under-reduction) were then corrected. However, mistakes rendering the tooth unsalvageable required students to start a new preparation on a fresh tooth. Their performance was then graded using a rubric detailing each step and justifying their grades. Students who failed the procedure were instructed to prepare another tooth to reach competency.

More broadly, the pandemic prompted us to deliver educational content differently. For laboratory sessions, we divided students into smaller groups attending laboratory sessions on different days of the week to ensure social distancing. Groups were smaller, resulting in a better staff to student ratio of 1:5 (vs. 1:10 previously). For lectures, we opted to deliver 50-minute virtual live lectures and seminars, which provided students with the opportunity to type in questions in the chat box and record the lectures for future use, which turned out to be a valuable and persistent teaching resource for students. For clinics, we again divided students into multiple mini-groups attending on different days of the week and maintained separation by using every other cubicle (open clinic). This “hybrid” teaching approach overcame some of the criticism of COVID dental education found in other institutions, namely that most of the online courses were in the form of lectures with a little practical training content (Liu et al., 2020, Farrokhi et al., 2021).

Live demonstrations, especially if used with a sufficient staff to student ratio, can be a valuable educational tool, especially when dealing with first exposure to new procedures. Additionally, live demonstrations are often performed by diverse faculty members with different dental backgrounds from different postgraduate schools. To standardize student performance, calibration between faculty members is manda-

tory prior to administering any laboratory procedure, as performed here. Other have reported that video clips or virtual demonstrations are an efficient teaching tool delivering good outcomes (Demirjian 1991, Kalwitzki 2005, Schitteck Janda et al., 2005), and these are now well accepted as teaching methods by undergraduates in other clinical disciplines, such as pediatric local anesthetic administration (Kenny et al., 2018). Videos have also been shown to be of benefit due to the use of magnified images and improving understanding of the concepts and hence development in behavioral skills (Robinson and Lee 2001). An intervention group (shown a magnified image of the degree of taper) retained the ability to perform an accurate taper one month and one year later compared with a control group receiving conventional teaching without the use of video aids. Moreover, videos allow students to replay part of all the procedure when required to reinforce the learning experience (Howell 1981).

Our experiences from the pandemic encouraged us to persist with the hybrid teaching approach. The staff to student ratio is now 1:6. Students are instructed to watch a video the day before the laboratory session and each faculty member then provides a live demonstration of the procedure to all six students at the start of the session. Following that, any struggling student receives a 1:1 live demonstration. Additionally, students must now use a verification guide (putty index) throughout the procedure to help self-assessment of the reduction and ensure adequate reduction throughout. Moreover, each preparation must be followed by a provisional crown.

This study had some limitations. The measurement location was not entirely reproducible. Each location refers to an area rather than a specific point, and the software does not offer a feature to number or label grids, so it was challenging to select the same point throughout the whole sample, as reflected in the variable intra-examiner reliability. However, the measurements are accurate and representative of the sample, as they were confined to specific locations measured by the same examiner throughout the procedure. The results of this study are specific to one dental school and may not be generalizable.

## 5. Conclusion

Student confidence increased throughout the year, meaning that they opted not to use verification guides and consequently delivered less-than-optimal reductions. Moreover, the use of virtual demonstrations with individual live demonstrations during COVID-19 resulted in different outcomes leaning towards a more conservative preparation. This study suggests that students should be offered both virtual and live demonstrations and should use reduction guides or digital scanners to self-assess reduction before submission for evaluation and to ensure adequate reductions. These verification methods can be as simple as putty indices or as advanced as optical scanners, but when used alongside virtual and live demonstrations, may ensure the best results.

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### Institutional Review Board Statement

The Research Ethics Committee of the Faculty of Dentistry at King Abdulaziz University Dental Hospital approved this retrospective study (KAUDH; Ref: 4429209).

### Informed Consent Statement

The need for informed consent was waived due to the retrospective nature of the study, and all participant data were anonymised for analysis within the study.

### Author Contribution

KMB conceived the study, collected the data, analysed the data, and wrote the manuscript.

### Data Availability

All raw data are available from the author on reasonable request.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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