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Variations between Visually Estimated and Actual Convergence Angles of Tooth Preparations

Thamer Y Marghalani*

Oral and Maxillofacial Prosthodontics Department, Fixed Prosthodontics Division, Faculty of Dentistry, King Abdulaziz University, Saudi Arabia

***Corresponding author:** Thamer Y Marghalani, Associate Professor and Consultant, Oral and Maxillofacial Prosthodontics Department, Fixed Prosthodontics Division, Faculty of Dentistry, King Abdulaziz University, Saudi Arabia, Tel: +966-567438377; E-mail: thamerdr@yahoo.com

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Abstract

Objectives: The purpose of this study was to compare the actual CA values of tooth preparations to those visually estimated by experienced prosthodontists, and to compare performance between prosthodontists.

Materials and methods: Three prosthodontists visually estimated the mesiodistal and buccolingual convergence angles (MDCA and BLCA, respectively) of 65 randomly selected premolar preparations made by dental students on typodonts. Preparations were scanned in three dimensions and digitized. Actual MDCA and BLCA values were measured by three-dimensional imaging software. Data were analyzed by Friedman test (α=.05) and pairwise multiple comparisons with the Bonferroni adjustment (α=.0042).

Results: The mean actual MDCA was 10.66 ± 3.96 degrees, compared to visual estimates of 13.86 ± 12.01, 21.94 ± 6.11, and 12.49 ± 8.38 degrees. The mean actual BLCA was 11.31 ± 4.80 degrees, compared to visual estimates of 13.32 ± 10.93, 23.52 ± 6.18, and 8.83 ± 5.75 degrees. The Friedman test resulted in $\chi^2(3) = 68.54$ ($P<.05$) for MDCA and $\chi^2(3) = 100.07$ ($P<.05$) for BLCA. Multiple comparisons indicated that two prosthodontists provided CA estimates that were similar to each other (MDCA, $P=1.0$; BLCA, $P=.042$) and to the actual CA values (MDCA, $P=.804$ and $P=.457$; BLCA, $P=1.0$ and $P=.006$), whereas one prosthodontists provided higher CA estimates compared to the actual CA values and the other prosthodontists ($P<.0042$).

Conclusions: One out of three of prosthodontists gave high CA estimates of tooth preparations compared to the actual CA and other prosthodontists' estimates.

Keywords: Convergence angle; Tooth preparation; Estimated; Actual; Scanned preparations.

Abbreviations:

CA: Convergence angle; 3D: Three-dimensional; BCLA: Buccolingual convergence angle; MDCA: Mesiodistal convergence angle

Introduction

Missing teeth and lost or defective tooth structures can be restored by various types of fixed prostheses, the retention of which can be achieved by many ways. The most important retention technique is minimizing the convergence angle (CA) to an optimal taper that allows proper seating and retention of the dental prosthesis. The CA, measured in degrees, is defined as the taper of a crown preparation or the angle formed between opposing axial walls when teeth are prepared for crowns or fixed dental prostheses. This term is best described as the total occlusal convergence [1]. CA values ranging from 4 to 38 degrees have been measured in the literature by various methods, including using a tool-maker microscope, geniometer, three-dimensional (3D) laser scanner, white-light 3D scanner, digitizer, AutoCAD photographs, Lava design, 3D-inspection software, and a protractor to measure a traced silhouette from a photo of the projection of dies [2-12]. Only one study mentioned using visual estimation to measure CA [8].

The operator should be able to assess the CA visually during tooth preparations. However, interoperator or interevaluator variation in the assessment and estimation of CA values has not been discussed much in the literature. Therefore, the purpose of this study was to compare actual CA values to those visually estimated by experienced prosthodontists, and to compare performance between prosthodontists. The null hypothesis was that the visually estimated CA does not vary from the actual CA or between operators.

Materials and Methods

In this observational study, tooth preparation characteristics and data were collected from typodonts on which dental students had prepared teeth for their annual practical exams. Among 126 preparations, 65 maxillary premolars that had been prepared for metal-ceramic veneer restorations were randomly selected for evaluation. Direct vision and interference from proctors, instructors, or evaluators were not allowed during the exam. The buccolingual convergence angle (BLCA) and mesiodistal convergence angle (MDCA) of the premolar tooth preparations were estimated by the naked eye by three experienced prosthodontists. The all three prosthodontists were either associate professors or professors with at

least 25 years of clinical experience. No calibration of the evaluators was attempted. No power analysis was performed.

The selected tooth preparations were scanned and digitized by an optical preparation scanner and digitizer (PrepScan, KAVO, Germany) to produce a 3D rendering. Then, the 3D digitization of each preparation was evaluated for the actual BLCA and MDCA. Measurements were performed with MeshLab Software (version 1.3.0, Dice Holdings Inc., NY, USA). One operator, other than the three prosthodontists, performed all measurements in the software.

Data were analyzed with the Statistical Package for Social Sciences software package (SPSS version 22.0, Chicago, IL, USA). Means and standard deviations (SDs) of the estimated and actual CAs were obtained. The differences between each prosthodontists estimated CA and the actual CA for each tooth preparation were calculated. Data were analyzed by the Friedman test at α=.05, and by pairwise multiple comparisons with the Bonferroni adjustment at α=.0042.

Results

Mean, SD, minimum, and maximum estimated and actual CA values are shown in Table 1. The mean actual MDCA was 10.66 ± 3.96 degrees, compared to visual estimates of 13.86 ± 12.01, 21.94 ± 6.11, and 12.49 ± 8.38 degrees. The mean actual BLCA was 11.31 ± 4.80 degrees, compared to visual estimates of 13.32 ± 10.93, 23.52 ± 6.18, and 8.83 ± 5.75 degrees.

Measured By	BLCA				MDCA			
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
Evaluator 1	13.32	10.93	0	50	13.86	12.01	0	45
Evaluator 2	23.52	6.17	10	40	21.94	6.11	10	35
Evaluator 3	8.83	5.75	0	30	12.49	8.38	0	40
Actual (digital scan)	11.31	4.8	4.39	24.64	10.66	3.96	2.59	21.07

Table 1: Mean and standard deviation of estimated and actual convergence angles. BLCA, buccolingual convergence angle; MDCA, mesiodistal convergence angle.

The counts and percentage of estimated CA values by each prosthodontist that were higher than, lower than, or the same as the actual CA values are shown in Table 2. The differences between each prosthodontists estimated CA and the actual CA for each tooth preparation were calculated and the counts (frequencies) and percentages of the differences are shown in table 2.

Angle	Difference between visually estimated and actual angles in degrees	Counts (%) of estimates with each difference		
		Evaluator 1	Evaluator 2	Evaluator 3
BLCA	> 20	5 (7.7)	5 (7.7)	1 (1.5)
	11 to 19.99	5 (7.7)	35 (53.8)	0 (0.0)
	6 to 10.99	7 (10.8)	13 (20.0)	5 (7.7)
	0.01 to 5.99	16 (24.6)	10 (15.4)	15 (23.1)
	0	0 (0.0)	0 (0.0)	0 (0.0)
	-0.01 to –5.99	20 (30.8)	1 (1.5)	27 (41.5)
	-6 to -10.99	9 (13.8)	1 (1.5)	12 (18.5)
	-11 to -19.99	3 (4.6)	0 (0.0)	5 (7.7)
	< -20	0 (0.0)	0 (0.0)	0 (0.0)
	Overestimates (n)	33	63	21
	Underestimates (n)	32	2	44
Total		65	65	65
MDCA	> 20	6 (9.2)	5 (7.7)	3 (4.6)
	11 to 19.99	7 (10.8)	31 (47.7)	6 (9.2)
	6 to 10.99	7 (10.8)	16 (24.6)	8 (12.3)

	0.01 to 5.99	14 (21.5)	10 (15.4)	19 (29.2)
	0	0 (0.0)	0 (0.0)	0 (0.0)
	-0.01 to –5.99	20 (30.8)	3 (4.6)	19 (29.2)
	-6 to -10.99	10 (15.4)	0 (0.0)	8 (12.3)
	-11 to -19.99	1 (1.5)	0 (0.0)	2 (3.1)
	< -20	0 (0.0)	0 (0.0)	0 (0.0)
	Overestimates (n)	34	62	36
	Underestimates (n)	31	3	29
Total		65	65	65

Table 2: Frequencies of differences betweenestimated and actual convergence angle and percentages of underestimates, overestimates, and correct estimates by each evaluator. BLCA, buccolingual convergence angle; MDCA, mesiodistal convergence angle.

The first evaluator overestimated and underestimated BLCA in 33, and 32 of the instances respectively, while the third evaluator had overestimated and underestimated in 21, and 44 of the instances respectively. The first evaluator overestimated and underestimated BLCA in 34, and 31 of the instances respectively, while the third evaluator had overestimated 36 and underestimated 29 of the instances. The second evaluator always overestimated in BLCA and MDCA in 63 and 62 of the instances respectively. The angle measurements were not normally distributed; therefore, the Friedman test and predetermined multiple comparisons were used. The Friedman test resulted in χ^2 (3)=68.54 (P<.05) for all MDCA values, and χ^2 (3)=100.07 (P<.05) for all BLCA values. Multiple comparison tests were performed with the Bonferroni correction and 12 comparisons per measurement (Table 3).

Comparison	Z	*P*-value
Actual MDCA / Evaluator 1 MDCA	-0.25	0.804
Actual MDCA / Evaluator 2 MDCA	-7.19	.000*
Actual MDCA / Evaluator 3 MDCA	-0.74	0.457
Actual BLCA / Evaluator 1 BLCA	0	1
Actual BLCA / Evaluator 2 BLCA	-7.44	.000*
Actual BLCA / Evaluator 3 BLCA	-2.73	0.006
Evaluator 2 MDCA / Evaluator 1 MDCA	-4.33	.000*
Evaluator 3 MDCA / Evaluator 1 MDCA	0	1
Evaluator 3 MDCA / Evaluator 2 MDCA	-6.45	.000*
Evaluator 2 BLCA / Evaluator 1 BLCA	-5.73	.000*
Evaluator 3 BLCA / Evaluator 1 BLCA	-2	0.045
Evaluator 3 BLCA / Evaluator 2 BLCA	-7.94	.000*

Table 3: Multiple comparisons of sign tests for estimated and actual convergence angles.

Two prosthodontists (Evaluator 1 and Evaluator 3) provided CA estimates that were close to the actual values for MDCA (P=.804 and P=.457) and BLCA (P=1.0 and P=.006), as well as close to the estimates of each other (MDCA P=1.0 and BLCA P=.042). The remaining prosthodontists (Evaluator 2) gave higher MDCA and BLCA estimates compared to the other prosthodontists and to the actual CA values (P<.0042).

Discussion

Differences were found between evaluators' estimates and the actual CA values, as well as between evaluators. Therefore, the hypothesis of the study was rejected.

The recorded actual CA values and visually estimated CA values found in this study were close to those reported in the literature [2-12]. Two of the three evaluators were able to estimate the CA close to the actual value, mostly within 6 degrees. One evaluator mostly overestimated the angles. All three evaluators estimated the angles freely, without selecting from angle options. Nick et al. [8] showed that most students and faculty members accurately estimated CA values of the same tooth preparations, which were milled on a surveyor. Differences between the estimated and actual CA values were within 10 degrees, and the estimates were mostly lower than the actual CA values. Accuracy decreased with increasing actual CA [8]. In contrast to the study by Nick et al. preparations in the current study were made by 65 dental students. Hence, each preparation was inherently unique.

Among the limitations of the study that there were no previous attempts of calibration for each evaluator to measure angles accurately and attempts eliminate the differences between the evaluators in estimation because the main objective of the study is to evaluate the accuracy of estimation without any interference and mainly based on the evaluators' experiences. Calibration attempts may affect the accuracy of estimation when considered in future studies. Measurements of visual acuity of the evaluators for near objects were not accounted for and not attempted in this study. The three evaluators used reading glasses and no special magnifying loupes were used during measurement by any of the evaluators.

In this study the three prosthodontists had 25 or more years of clinical experience. These prosthodontists were still able to estimate the angles close to the actual angles. Future studies may include different educational backgrounds and variable ranges of clinical years of experience.

Conclusion

Within the limitation of the study, the following conclusions can be made:

- Two out of three prosthodontists gave visual estimates that were very close to the actual CA values.
- One out of three prosthodontists provided CA estimates that were higher than the actual CA values and higher than the other prosthodontists' estimates.

Conflict of Interest

The author denies any financial interest or any conflict of interest exists.

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