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Original Article

A research into the capability of estimating the total occlusal convergence of CAD/CAM teeth by dental school faculties and dental students

Shujiao Qian[1], Xinyu Zhang[2], Guo Bai[3], Jian Sun[4,5,6]

Departments of [1]Oral Implantology, [2]Oral-Maxillofacial Head and Neck Oncology, [3]Oral Surgery, [4]Prosthodontics, Shanghai Ninth People's Hospital, College of Stomatology, Shanghai Jiao Tong University School of Medicine, Shanghai, China; [5]National Clinical Research Center for Oral Diseases, Shanghai, China; [6]Shanghai Key Laboratory of Stomatology and Shanghai Research Institute of Stomatology, Shanghai, China

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Abstract: To investigate the capability of dental school faculties and dental students to assess the ideal total occlusal convergences (TOCs), 5 anterior and 12 posterior typodont teeth were prepared with TOCs ranging from 0 to 12 degrees for anterior teeth and -3 to 30 degrees for posterior teeth. The prepared teeth were put into a model with at least one unprepared tooth on each side. 36 faculties and 38 students were asked to identify the prepared teeth with ideal, maximally acceptable or minimally acceptable TOCs and make estimations of the TOC values respectively. Chi-Square test was used to test the difference in accuracy rate between faculties and students. The comparison of estimation capability of tooth TOCs between these two groups was completed by Wilcoxon rank sum test (α=.05). 6 degrees for anterior teeth and 9 degrees for posterior teeth were the most frequently chosen ideal TOCs. The majority of the faculties and students offered correct TOC estimations of the anterior teeth. However, both groups tended to underestimate the actual TOCs of the posterior teeth. The results provided by faculties were closer to the actual values of posterior tooth TOCs. Although most of the participants had difficulties in estimating TOC values, clinical experience made some difference to the visual estimation capability. Overall, our study indicates that visual TOC estimation by dental school faculties and students for the anterior teeth is more accurate than that of the posterior teeth.

Keywords: Total occlusal convergence, visual estimation, computer-aided design, dental abutments

Introduction

Total occlusal convergence (TOC), defined as the convergence angle formed by the opposing walls of a tooth prepared for an artificial crown, is one of the necessary prerequisites for fabrication of fixed prosthetic restorations [1, 2]. Studies have confirmed that TOCs have a direct influence on the resistance and retention form of the crowns [3-5].

TOCs of 4 to 6 degrees had been suggested by textbooks as optimal for full crown preparation and arange of 4 to 14 degrees had been suggested as acceptable [6, 7]. However, studies have shown that these scientifically based recommendations could hardly be met in daily clinical practice. Charles T. Smith compared two groups of preclinical dental students working on typodonts. The taper criteria for tooth preparation were 6 degrees and 12 degrees respectively. The results indicated that the overall mean taper for each group exceeded the targeted criterion and the use of a 12-degree taper criterion did not result in students achieving the goal of a 12-degree taper [8]. In a descriptive cross-sectional study of 197 crown models prepared by dental residents and specialists, a considerable disparity was found between the TOCs recorded in the study and the recommended values [9].

The incapability of accomplishing the optimal TOC preparation may be partly explained by the fact that visually estimating TOCs can be difficult in both laboratory and clinical scenarios.

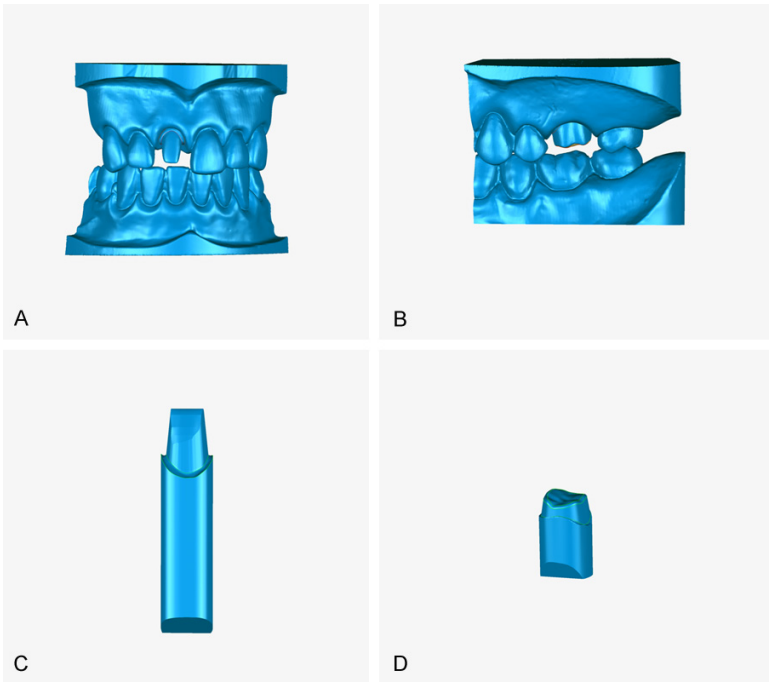

Figure 1. A. Standard digital model of maxillary central incisor with neighboring and opposing teeth. B. Standard digital model of maxillary first molar with neighboring and opposing teeth. C. Design of central incisor with TOC of 9 degrees. D. Design of maxillary first molar with TOC of 6 degrees.

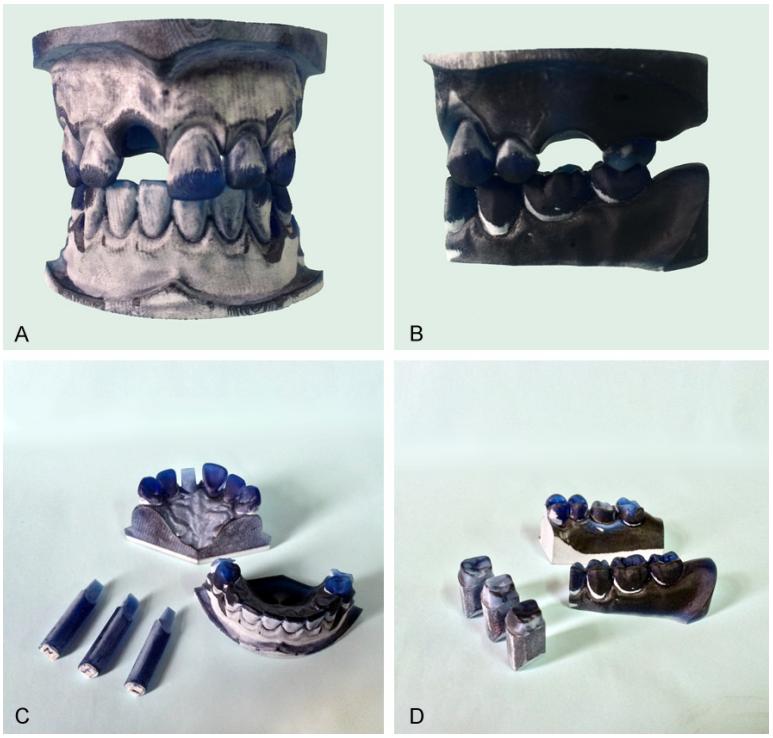

Figure 2. A. Models including one vacant site for the prepared central incisor. B. Models including one vacant site for the prepared first molar. C. Prepared central incisors of specific TOC angles inserted into the model for identification. D. Prepared maxillary first molars of specific TOC angles inserted into the model for identification.

TOCs prepared in clinical practice may deviate much from the recommended ideal which the dentists plan to fabricate, since it is challenging to determine if the TOCs are appropriate based on visual estimation.

Although there are abundant data on the TOC values achieved both pre-clinically and clinically [10-12], the accuracy with which dental school faculties and dental students visually assess TOCs and the effect of operators' clinical experience on the TOC estimation capability need further investigation. Therefore, the primary purpose of the present study was to identify the TOCs considered to be ideal, maximally acceptable, minimally acceptable by dental school faculties and dental students in the department of prosthodontics and to investigate their estimation capability towards these selected angles. The second purpose was to test whether the accuracy of estimations between anterior and posterior tooth would be differed. The null hypothesis was that the TOC estimations offered by dental school faculties and dental students wouldn't deviate from the actual values.

Materials and methods

Standard digital models of maxillary central incisor and first molar (**Figure 1**) with at least one neighboring tooth on each side were obtained by CT scanning (GE lightspeed 16, 120 kV, MAS 210, General Electric Company, USA). These digitized data were reconstructed into solid 3D images, using Geomagic Studio 12.0 (Geomagic (Sh-

Table 1. Study form for each participant

Tooth position		Bottom number of the tooth you selected	TOC estimation of the tooth you selected
Posterior tooth	Ideal TOC		
	Maximally acceptable TOC		
	Minimally acceptable TOC		
Anterior tooth	Ideal TOC		
	Maximally acceptable TOC		
	Minimally acceptable TOC		

Table 2. TOCs of anterior teeth selected as ideal, maximal, and minimal

Participant	Anterior tooth (degrees)	0	3	6	9	12
Faculty	Ideal TOC	0	12	22	2	0
	Maximally acceptable TOC	1	1	4	22	8
	Minimally acceptable TOC	8	24	2	1	1
Student	Ideal TOC	0	15	22	1	0
	Maximally acceptable TOC	0	0	11	24	3
	Minimally acceptable TOC	10	22	4	1	1

anghai) Software Co., Ltd). Designs of 5 prepared central incisors and 12 prepared first molars with specific TOCs (CAD images) were accomplished based on standard models. Each of the central incisors was prepared with one of the following TOCs: 0, 3, 6, 9, 12 degrees. And the first molars: -3, 0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30 degrees (**Figure 1**). With rapid prototyping technique, models including one vacancy for the prepared teeth and at least one neighboring tooth on each side were printed out, along with their opposing models (3D Systems ProJet™ HD3500 3D printer). Prepared teeth with specific TOC were placed randomly into models for identification and distinguished themselves by randomized numbers on the bottom (**Figure 2**).

Thirty-six dental faculties with at least three-year clinic experience and 38 dental students doing internship in the Department of Prosthetics in Shanghai Ninth People's Hospital were randomly selected to choose specific teeth with the TOCs they believed to be the ideal, maximally acceptable, minimally acceptable and respond to the following questions (**Table 1**).

Common room illumination and clinic environment were ensured. Every participant finished the questionnaire independently and the order of the prepared teeth was reorganized each time a new participant began.

Choices of tooth with specific TOC were interpreted from the written numbers on the bottom to the actual angles. The estimations offered by participants were compared with the actual TOC values of the teeth they selected. The correct estimation was defined in a way that the estimation was consistent with the actual TOC value. Data were extracted and put into tables. All tests were performed using SPSS 20 (IBM SPSS Statistics, Armonk, NY, USA). Chi-Square and Wilcoxon rank sum test were used to analyze the data and statistical significance was set at 5%.

Results

Regarding the anterior teeth with TOCs ranging from 0 to 12 degrees, the TOCs commonly selected as ideal were 3 and 6 degrees in both groups. Six-degree TOC was chosen most frequently by 22 subjects in both groups. 12 faculties and 15 students chose 3 degrees, making it the second popular ideal TOC for anterior teeth. No one chose 0 or 9 degrees in either group (**Table 2**).

As for the posterior teeth, half of the faculties (18 out of 36) took 9 degrees as the ideal angle. The popular choices of the faculty group were confined to the range of 6 to 12 degrees. Five participants chose 6 degrees, four chose 12 degrees and only one dental faculty took 15 degrees as the ideal. A similar situation could be observed in the student group. 14 out of 38 students chose TOC of 9 degrees as the most ideal angle, making it the most common selection among students. However, the other popular options for students were 12, 15, and finally 6 degrees, with 8, 7 and 5 participants making the choice respectively (**Table 3**).

Table 3. TOCs of posterior teeth selected as ideal, maximal, and minimal

Participant	Posterior tooth (degrees)	-3	0	3	6	9	12	15	18	21	24	27	30
Faculty	Ideal TOC	1	1	2	5	18	4	1	1	1	2	0	0
	Maximally acceptable TOC	0	0	0	1	2	9	14	5	2	0	0	3
	Minimally acceptable TOC	5	7	11	10	2	1	0	0	0	0	0	0
Student	Ideal TOC	0	0	1	5	14	8	7	0	2	0	1	0
	Maximally acceptable TOC	0	0	2	0	5	5	8	8	6	2	1	1
	Minimally acceptable TOC	3	2	9	11	6	3	2	1	0	0	0	0

Table 4. TOC estimation accuracy

Tooth location	Participant	Number of correct estimation	Number of underestimation n (%)			Number of overestimation n (%)			*P* value
			(0, 5)	[5, 10]	[10, +∞]	(0, 5)	[5, 10)	[10, +∞]	
Anterior	Faculty	69	15 (13.89)	3 (2.78)	0 (0.00)	14 (12.96)	6 (5.56)	1 (0.93)	0.6068
Tooth	Student	72	22 (19.30)	8 (7.02)	1 (0.88)	7 (6.14)	4 (3.51)	0 (0.00)	
P value		0.9100							
Posterior	Faculty	27	31 (28.70)	26 (24.07)	8 (7.41)	10 (9.26)	6 (5.56)	0 (0.00)	0.0002**
Tooth	Student	13	24 (21.05)	53 (46.49)	13 (11.40)	5 (4.39)	6 (5.26)	0 (0.00)	
P value		0.0084*							

*Statistically significant difference in the accuracy rate of TOC estimation of posterior teeth between faculties and students. **Statistically significant difference in the estimation capability of posterior tooth TOCs between faculties and students.

When the participants chose the anterior teeth with TOCs believed to be the maximally acceptable, 9 degrees' TOC was the most popular option in both groups. There were also 8 participants choosing 12 degrees in the faculty group and 11 choosing 6 degrees in the student group. Speaking of the posterior teeth, 15 degrees' TOC was chosen most frequently by 14 faculties. However, the popular choices of students ranged from 9 degrees to 21 degrees, among which 15 degrees and 18 degrees were the most common selections (**Tables 2**, **3**).

The results of the minimally acceptable TOC of tooth were almost the same in both groups. The most popular choice of anterior teeth was 3 degrees, and of posterior teeth were 3 and 6 degrees (**Tables 2**, **3**).

The visual preference and the accuracy of estimation of both groups could be seen from the above table (**Table 4**), which included the number of certain estimation.

For anterior teeth, most of the estimations were correct (69 out of 108 estimations in faculty group and 72 out of 114 in student group). No significant difference in accuracy rate between faculties and students was observed as indicated by Chi-square test (p=.9100). Moreover, no significant difference in the visual assessment capability of anterior tooth TOC between these two groups could be detected by Wilcoxon rank sum test (P=.6068).

When it comes to posterior teeth, 27 estimations offered by faculties and 13 by students were correct. Chi-square test revealed a significant difference in the accuracy rate between faculties and students (P=.0084). With Wilcoxon rank sum test, the difference in the estimation capability of posterior tooth TOCs between these two groups was statistically significant (p=.0002). The results provided by faculties were closer to the actual TOC values. Sixty-eight (62.96%) estimations provided by faculties were within 0-5 degrees or less of the actual angle, 32 (29.63%) estimations were inaccurate by 5-10 degrees and 8 (7.41%) were overestimated by more than 10 degrees. However, for the 114 estimations offered by students, only 42 (36.84%) were within 0-5 degrees or less of the actual measurement, 59 (51.75%) being inaccurate by 5-10 degrees and 13 (11.40%) more than 10 degrees.

Both faculties and students tended to offer correct estimations of the anterior teeth. But they tended to underestimate the actual TOCs of the posterior teeth. Using Chi-square test, the estimation of anterior teeth demonstrated a higher accurate rate compared to the posterior teeth

in both groups (p<.0001). Among those incorrect estimations, posterior teeth were more often underestimated than anterior teeth (p=.0002 for the faculty group and p=.0209 for the student group).

Discussion

No consensus has been achieved as to the ideal or acceptable TOC for tooth preparation, with the ideal TOC values ranging from 2 to 5 degrees to 10 to 20 degrees [13-16]. In this study, the ideal or acceptable range of TOC fell well within the range recommended by previously published literature [4, 7, 9]. The result was also consistent with a previous study, where teeth prepared with TOCs of 9 degrees and 12 degrees were the most popular choices as the ideal by both faculty and student participants [17].

However, it's one thing to decide upon the ideal or acceptable range of TOC, another to offer the correct estimation. The results of the study rejected the stated null hypothesis that the TOC estimations offered by faculties and students wouldn't deviate from the actual values. Only 44.44% of the estimations made by faculties and 37.28% by students were correct. This finding, along with results from previous studies [18-20], showed that visually estimating TOCs could be difficult.

Moreover, our results showed that clinical experience made a difference to the visual estimation capability towards posterior teeth. The faculty participants exhibited a higher accuracy rate than the student participants. Most of the faculties were incorrect by less than 5 degrees. Wilcoxon rank sum test revealed that results provided by faculties were closer to the actual TOC value compared to students. This result reminded us of the importance of deliberate training and practice for visual TOC estimation, especially for dental students.

To the best of our knowledge, this study was the first to investigate visual TOC estimation skills of dental professionals with specialized CAD/CAM models. Instead of milling typodont teeth in a conventional way, model preparation was accomplished with rapid prototyping technique. This method guaranteed the accuracy and reproducibility of model preparation. Moreover, the presence of neighboring and opposing teeth in the study offered better simulation of clinical scenario. This was more favorable than single prepared teeth mounted in resin holders as indicated in the previous study [17].

Digital approaches based on the analysis of digital surface tessellation language (STL) data were reported as useful methods in preclinical simulation [21-22]. Solid 3D images were reconstructed by scanning the preparations with specialized metrology equipment and TOC values were determined. Reliable results were reported of these newly emerging digital assessment tools [23-26]. Our study offered another method of combining digital data with traditional teaching. The CAD/CAM typodont models presented in this study might serve as future teaching tools by offering direct-viewing understanding. Overall, more efforts should be made to integrate digital methods such as CAD/CAM typodont models and computer-assisted assessment into deliberate training for visual TOC estimation.

It is worth mentioning that both faculties and students tended to offer more underestimations than overestimations of the actual posterior tooth TOCs. This may be one of the reasons why posterior teeth were always prepared with greater TOC than anterior teeth in clinical practice. Besides, estimations of anterior teeth were more accurate than the posterior ones. This can be at least partially explained by the fact that the TOC range of posterior teeth we offered was wider than the anterior one. Selection among 5 anterior teeth might be less stressful than among 12 posterior teeth.

This study was limited by the sample size, tooth position and tooth color. Besides, the in vitro study failed to mimic the clinical situation where teeth were surrounded by other structures. Future studies about training methods of visual estimation skills should be conducted.

Within the limitations of this study, our results showed that most dental professionals seemed to have difficulties in offering accurate estimation of TOC values. Anterior tooth TOC estimation by the subjects was more accurate than the posterior estimation. Clinical experience made a difference to the visual estimation capability. Therefore, deliberate training with a special emphasis on modern digital teaching

methods is essential for acquiring visual estimation skills.

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Disclosure of conflict of interest

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Address correspondence to: Dr. Jian Sun, Department of Prosthodontics, Shanghai Ninth People's Hospital, College of Stomatology, Shanghai Jiao Tong University School of Medicine; National Clinical Research Center for Oral Diseases; Shanghai Key Laboratory of Stomatology and Shanghai Research Institute of Stomatology, No. 639, Zhizaoju Road, Shanghai 200011, China. Tel: +862123271699-5695; E-mail: doctorsunjian74@aliyun.com

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