Change of convergence angle depending on distance between clinical abutment teeth

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ABSTRACT

The clinical knowledge and skills of dental students attending to different Swedish universities is constantly under discussion. In this study ten students attending their eighth semester at the Department of Odontology, Faculty of Medicine, Umea University Sweden were recruited to evaluate if it would be more challenging to prepare abutment teeth for fixed partial dentures (FPD) with the abutment teeth far apart in the dental arch. Questioning whether it is more difficult to achieve an adequate total convergence angle (TOC) for FPD with abutment teeth closer to each other than one with them further apart. The hypothesis that teeth further apart give a larger TOC. For the experiment the students used dental mannequins with plastic maxillae and plastic teeth provided by the simulation clinic at the university. Their task was to prepare for two separate FPD, one with the abutment teeth 14; 16 and a second 21; 13; 15. After preparation, the teeth were drilled and had metal posts placed in them, the posts representing a normal that the TOC could be measured against. Still photos of the plastic maxillae were taken using the program Shape 3D Viewer. A tangent was drawn to measure the TOC. An adequate TOC for crown retention was considered: 10-22 degrees in both mesio-distal and bucco-palatinal plane axis. The results for the two tested models of FPD were relatively similar, likely because the students got to practice preparation for the shorter and FPD first. In conclusion, this study showed no noteworthy difference between the first and second FPD preparation.

INTRODUCTION

When treating a tooth with dental prosthetics the preparation, i.e. the retentive aspect, is important for the success of the restoration (Milleding, 2012). The total occlusal convergence angle (TOC) is an angle composed of two tooth axial walls, either mesio-distal or bucco-palatinal (Milleding, 2012). This angle affects the retention and resistance of the fixed partial dentures (FPD), where the retention and resistance properties are proportional to each other (Muruppel *et al.*, 2018). The FPD might not have a satisfactory seating and could have an inadequate path of insertion if the axial walls have a preparation design which is parallel or contains undercuts.

There are different opinions in the literature regarding the definition of an appropriate TOC when preparing a tooth. For example, the prosthetic textbook recommended to the students attending the Department of Odontology, Faculty of Medicine, Umea University Sweden claims that "For convergence angles above 10 to 15 degrees, a considerable loss of retention is observed" (Nilner *et al.* 2013). In other literature, a TOC between 10 to 22 degrees was considered acceptable (Shillingsburgh *et al.* 1997). Kharat et al. performed a study on dies where the conclusion was that a 20-degree TOC shows better seating of single crowns and FPD (Kharat *et al*. 2015). The 20-degree TOC however compromised the retention and resistance of the dentures, therefore a TOC of 12 degrees was suggested (Kharat *et al*. 2015).

Additional aspects need to be taken into consideration when preparing for an FPD. Firstly, the abutment teeth should be prepared in relation to each other considering their vertical wall tapers. This is shown to influence the FPD rotational resistance, as concluded in a recent study by Bowley (Bowley J.F *et al.* 2017). It was shown that low levels of vertical wall taper, with 7 to 10 degrees favorable, were needed to resist rotational displacement in FPD (Bowley J.F *et al.* 2017). Secondly the vertical preparation height must be considered. If the abutment tooth suffered an extensive loss of tooth substance or if too much of the vertical height is removed during preparation, this may later affect the crown retention. For example, for a premolar it is appropriate to maintain a 3-4 mm vertical preparation height, also known as "cylinder for retention" (Milleding. P, 2012).

Measuring the TOC can be problematic and getting perfectly accurate TOC can be difficult. To facilitate measurements, the preparations can be scanned using a computer aided design (CAD) scanner and then printed and manually measured on paper (Aleisa *et al.* 2013). The TOC can also be measured directly in the computer, where a variety of different programs exist that can aid in angle measurement.

The aim of this study was to measure the TOC of teeth prepared for two separate FPD with the abutment teeth positioned differently in the dental arch. The first FPD with two abutment teeth, premolar and molar, and the second with three abutment teeth also including an incisor. One FPD with abutment teeth purposely placed on either side of the centerline. The question at issue being if the distance between the abutment teeth will affect the preparation standard and whether every tooth will have adequate TOC to retain a single crown. Another purpose of this study was to use the results for guidance on how many hours of practice students will need at the university simulation clinic.

The student's ability to maintain a proper tooth preparation technique will be evaluated and consequently assessing the education provided to the students. In short, the clinical skill, in terms of preparation, of the students at the Department of Odontology, Faculty of Medicine, Umea University Sweden will be evaluated.

The working hypothesis claiming that the further apart from each other the teeth are in the dental arch, subsequently the higher TOC the students will prepare in order to balance out the difficulty of preparing all teeth in relation to each other. And with the higher TOC the teeth on the three-unit FDP will be at risk of not retaining a single crown.

Comparable studies have been executed at other universities, for example fifth year students at King Abdulaziz University in Saudi Arabia prepared teeth for metal ceramic restorations and the average TOC produced was between 10,16 and 11,46 degrees (Marghalani TY, 2014). At King Saud University, also in Saudi Arabia, another study was made with last year students where the overall mean TOC for single crowns and FPD was 18,56 degrees, but a variation was seen on the TOC, for example anterior teeth had a smaller mean TOC (Aleisa *et al.*, 2013).

MATERIALS & METHODS

Participants

Ten dental students (three male, seven females, mean age 24) attending their eighth semester at the Department of Odontology, Faculty of Medicine, Umea University, Sweden were recruited for this observational study. A post was made in the class group on a social media website explaining that ten students were needed for preparation and it would take an afternoon of their time. The first ten volunteering students had the opportunity to participate. All participants received compensation in the form of two lottery scratch cards each.

Conditions of preparation

The students were instructed to prepare teeth for two different FPDs:

1. Full ceramic bridge in the first quadrant with the abutment teeth consisting of the first molar and first premolar.

2. Full ceramic bridge crossing the midline in the upper jaw with abutment teeth consisting the second premolar and canine in the first quadrant and the central incisor in the second quadrant.

All teeth except for those in need of replacement with the hypothetical FPD were placed in the maxilla, simulating a more realistic scenario with neighboring teeth for the students to be cautious of not damaging. The counter bite, a complete mandible, had been placed in the dental mannequins with the correct occlusion already set up. Instructions given to the students before preparation were to maintain the given timeframe which was 90 min for the first FPD with two abutments and 120 min for the second with three abutments. The students were also reminded to prepare so that the axial walls of the teeth rather be slightly angled than completely parallel, reminding them that the TOC is what will be measured. The students were also told to prepare the abutment teeth considering their relation to one another so that a hypothetical fixed partial denture would fit.

Placement of posts

In order to measure the TOC of each individual plastic tooth a reference for the FPD

direction of insertion was provided to each tooth in the shape of a thin metal post. This was done after the students finished preparations, for the experiment to be as natural as possible and not mislead or aid the students during the preparation. For each one of the teeth used in the hypothetical FPD the central part of the occlusal, or palatal surfaces were drilled using a drill press. By placing the plastic maxilla on the table of the drill press, the manner and direction of drilling was the same on all teeth. Therefore, the posts will be parallel and can represent a normal to which tangent can be drawn and each axial angle measured.

Scanning and measuring

The plastic maxillae were scanned using the 3Shape D2000 dental lab scanner at the university dental technician laboratory. The scanned models were then imported to 3Shape 3D viewer, where 2D cross sections with the teeth and posts correctly positioned were taken. Several snapshots were taken to measure both the bucco-palatinal TOC and mesio-distal TOC. These cross sections where later imported to Autodesk AutoCAD 2018 where tangents were drawn, from which the angles were measured. Tangents were drawn out and measured three times on each axial surface of the tooth (mesial, buccal, distal, palatal) for a smaller margin of error. On one axial surface, the buccal of the first molar, the measuring was repeated ten times for each student which gave the total mean standard error value of 0,203621 degrees. The measurements of TOC were performed by one examiner (JL) as to avoid the risk of differences in measurement between observers.

Search for literature

The search for literature was made using PubMed database and consisted of articles published in the last 5 years. When first searching, a PubMed search was executed were terms such as "convergence angle", "retention", "tooth preparation design", etc., were used. Later another search was made on PubMed using MeSH-terms, of articles published in the last 5 years. The MeSH-terms used were “tooth preparation, prosthodontic”, “dental abutments” and “denture, partial”. The term “tooth preparation, prosthodontic” gave 205 items. The term “Dental prosthesis retention” gave 2524 items. The term “Dental abutments” with 836 items. The term “denture, partial” gave 1001 items. When the term “dental abutments” was put together with the term “denture,

partial" 164 items were found. Combining the terms "dental abutments" together with "tooth preparation, prosthodontic" yielded 26 items.

Statistical analysis

Data was collected and analyzed using boxplot and t-test. When performing a quantitative t-test the data was split into two groups, failed (0) and passed (1). The limit for passing was set between 10-22 degrees and the remaining data was marked as failed.

Ethical considerations

Firstly, an application was sent to The Ethics Forum at the Department of Odontology for approval of the study.

To motivate the students to participate in the study, they were told that after their preparations were finished, they would receive two lottery scratch cards each. They were given mainly as motivation, but also as a sign of appreciation to the students. Ethically this could have led difficult scenarios in the unlikely case of a student winning a large sum of money after participating in this study.

The main ethical consideration of this study, however, revolves around the ten students performing the preparations. When recruiting the students, it was made clear that their TOC results would be handled anonymously, very much like during their exams. Thus, ensuring that neither the teacher conducting the study nor the two students executing it could know which preparations belonged to which student. At the day of the preparations, the students were therefore given a paper bag. In the bag there was an envelope, marked with a number between one and ten. The envelope, in turn, contained a note marked with a number between one and ten, on which the students would write their name. When they were finished, they would detach their plastic maxillae from their dental mannequins and place them in the bag. For the anonymity, a third party was recruited as a keeper of the little notes. From the notes he produced a list of the numbers connected to the names of the students, in case of a student forgetting their number.

When further debating the ethics of this study it must be considered that the study was performed on a class of students with no previous access to the simulation clinic. The construction of the simulation clinic was finished a few weeks before this study and this year of students did not have scheduled classes beforehand at this clinic. However,

students attending lower semesters of the College of Dentistry at Umea University will have many hours in the simulation clinic, as an extra preclinical practice built into their curriculum.

RESULTS

When analysing the preparations, the assessment was made that all preparations had an adequate preparation height. Furthermore, all students were able to finish preparations for both bridges within the determined timeframes.

All the measured TOC are presented in Table 1. The adequate TOC that are 10-22 degrees, are marked green, and the negative TOC marked red. 44% of all the measured angles in the shorter FDP were within the accepted TOC and 4% of the abutment walls showed a negative angle. The results from the long FDP showed 43% within the accepted TOC range and 8% undercuts.

Green marked TOC in both mesio-distal and bucco-palatinal plane axis simultaneously were for the teeth 14 30%, 16 20%, 21 20%, 13 30% and 15 20%. When only viewing bucco-palatinal TOC the values were 14 70%, 16 50%, 21 40%, 13 50% and 15 40%.

Comparing the preparation results between the angles that were furthest apart in mesio-distal direction showed that four out of ten students (40%) were able to prepare the short FPD abutment teeth within a TOC of 10-22 degrees, while seven out of ten (70%) succeeded with the longer FPD (Figure 3).

DISCUSSION

Regarding the ethics of this study, this class from which ten students have been picked is at a probable disadvantage in comparison to the younger students of the Department of Odontology, Faculty of Medicine, Umea University, Sweden. This is believed because of the added preclinical practice the younger students will receive due to the results of this study. They will spend many hours in the simulation clinic preparing plastic teeth for single crown and FPD, something the students performing this study never had a chance to do. This will clearly give the younger students at this university an advantage when beginning their work with patients at the university clinic. For this reason, the semesters lower than the one with students performing this study will most likely end up with more clinical skills in this area after graduating from the College of Dentistry at Umea University.

The thought of placing a thin metal post in each plastic tooth stemmed from the need of a fixed perpendicular point to which each convergence angle could be measured. Estimating that the error value would become significantly smaller with this fixed point in the center of each plastic abutment tooth. However, the placement of the metal posts can provide a small margin an error, later affecting the measuring. To provide the posts an identical placement in each of the ten samples of each tooth is not possible. This can be particularly difficult in incisors where the tooth itself is angled buccally in the dental arch.

When viewing the mean standard error value of 0,203621 degrees the assessment was made that the method of measuring did not yield a particularly big margin for error. The standard error value varied slightly between the students and it is likely that this stems in the different preparation techniques leading to some students having more even preparations and others having more rough preparations which can prove more difficult to measure.

Teeth that according to TOC 10-22 degrees can retain a crown regarding adequate TOC in both mesio-distal and bucco-palatinal regard was for the abutment teeth 14 30%, 16 20%, 21 20%, 13 30% and 15 20%. However, when viewing the question in a more clinically significant manner and judging the whether a crown will retain on the bucco-

palatinal TOC the percentage of abutment teeth with possible crown retention were 14 70%, 16 50%, 21 40%, 13 50% and 15 40%. It is a matter of which angles are considered most significant for the retention of the FPD. Most of the students had not prepared for FPD in approximately two and a half years aside from a few that had prepared on one or two patients. This meaning that the first FPD preparation, was for some like a warming up and practicing once more something they had not in a long time. Between preparing the two FPD the students had a break and discussed the preparation task with each other. This could explain why this smaller FPD did not yield significantly superior TOC in comparison to the longer FPD, as had been the hypothesis.

One of the students had preparations with multiple teeth prepared with undercuts and negative TOC. This is believed to have affected the overall average of each TOC and the removing of this students' data was discussed. Although, when statistically tested, this data did not prove deviant enough to remove from the analysis. The rather small sample size of ten students is a limitation to this study.

The question if teeth are more difficult to prepare adequately with the teeth further apart from each other in the dental arch, has been shown very difficult to provide a good answer too. There is a lack of research in the matter and it is very difficult to find a relevant way of measuring this. Although it is of clinical belief that this is surely the case.

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TABLES

Table 1. Measured total occlusal convergence angle (TOC) in degrees of the (A) shorter fixed partial denture 14[15]16 and the (B) fixed partial denture crossing the midline 21[11,12]13[14]15 for all participants (students. The TOC that are within 10-22 degrees are marked in green and the negative TOC are marked in red.

A.

Student	14md	14bp	16md	16bp	14-16md
1	30,05	8,71	23,19	7,58	29,88
2	9,93	13,95	2,23	15,63	-1,52
3	-6,57	12,78	26,66	25,39	7,07
4	10,66	18,31	36,91	23,06	19,66
5	29,11	21,77	44,16	17,35	36,54
6	15,72	3,31	14,78	14,59	19,01
7	27,56	6,84	31,31	17,96	23,93
8	32,60	19,27	33,70	7,45	34,82
9	11,69	13,15	20,94	11,06	18,93
10	15,00	20,64	12,95	9,81	14,05
Average	17,58	13,87	24,68	14,99	20,24

B.

Student	21md	21bp	13md1	13md2	13bp	21d-13d	15md	15bp	13-15md	21d-15d
1	21,75	13,04	17,37	17,15	17,31	14,58	33,09	6,01	25,32	16,41
2	6,45	21,19	5,26	7,19	-1,40	-9,99	1,00	-4,18	-4,21	-22,11
3	10,76	20,06	23,93	35,41	19,84	10,70	24,20	18,38	37,56	16,28
4	4,79	5,26	22,37	7,25	20,64	7,82	16,97	8,15	5,67	7,99
5	24,38	27,93	23,77	22,68	42,99	15,16	19,48	33,82	10,75	17,78
6	14,63	29,71	48,30	39,14	34,27	17,39	22,90	20,72	20,18	12,87
7	44,84	27,89	27,13	24,77	31,98	26,01	30,97	14,45	22,63	18,59
8	-0,85	19,49	8,73	9,89	10,39	-4,41	11,93	-3,19	0,46	5,93
9	18,44	25,40	17,83	19,95	14,52	16,66	14,17	20,50	15,80	13,70
10	6,13	0,40	14,53	18,16	25,87	4,63	16,44	9,33	25,38	11,06
Average	15,13	19,04	20,92	20,16	21,64	9,85	19,12	12,40	15,95	9,85

FIGURES

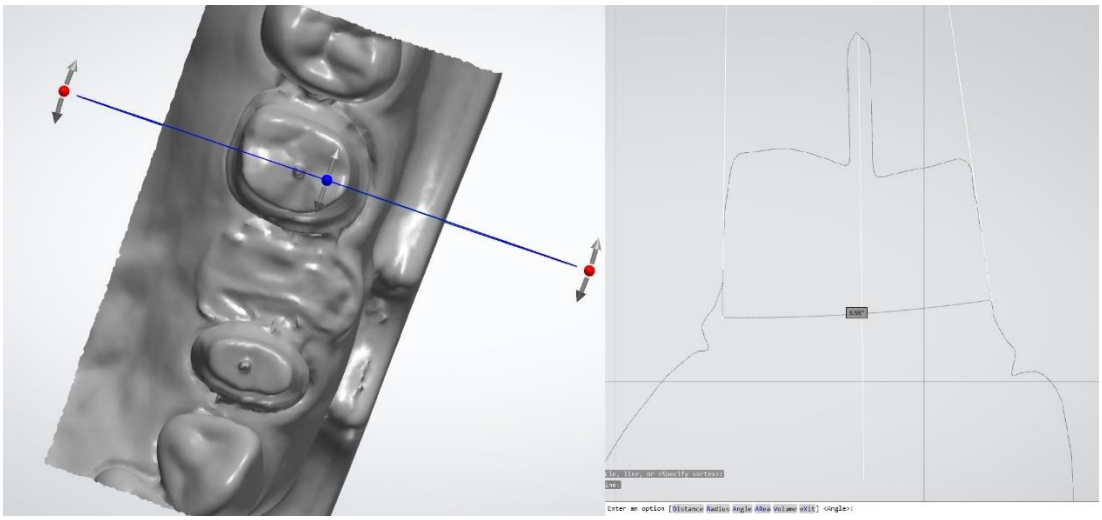

Figure 1. Bucco-palatinal 2D cross section of molar in the three unit fixed partial denture in Shape 3D viewer and angle measurement in Autodesk AutoCAD 2018.

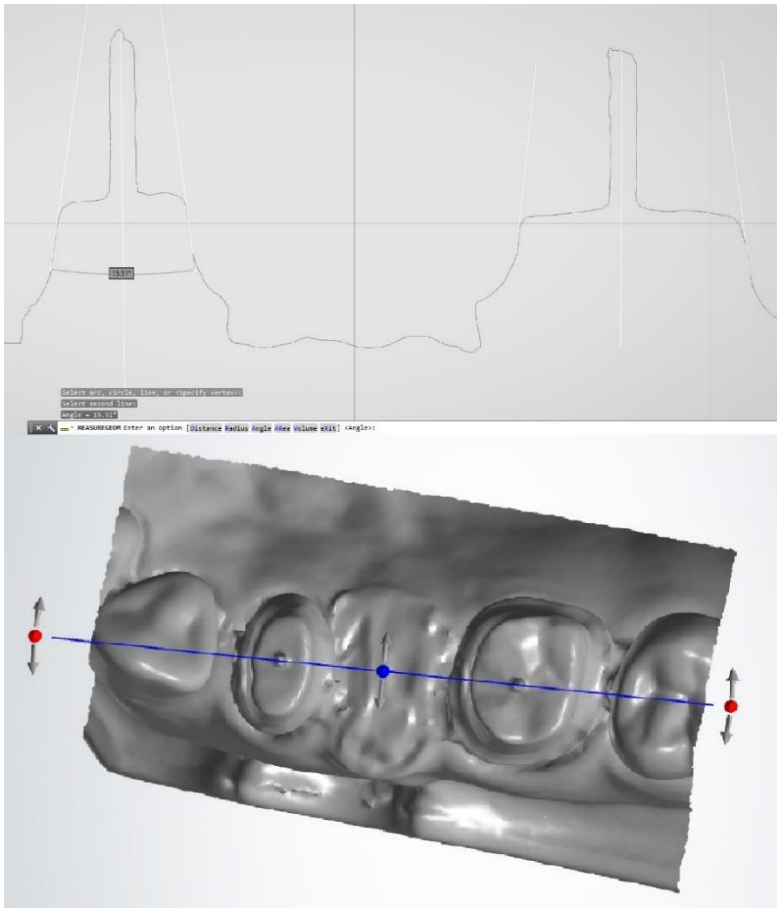

Figure 2. Mesio-distal 2D cross section of premolar and molar in the three unit fixed partial denture in Shape 3D viewer and angle measurement in Autodesk AutoCAD 2018.

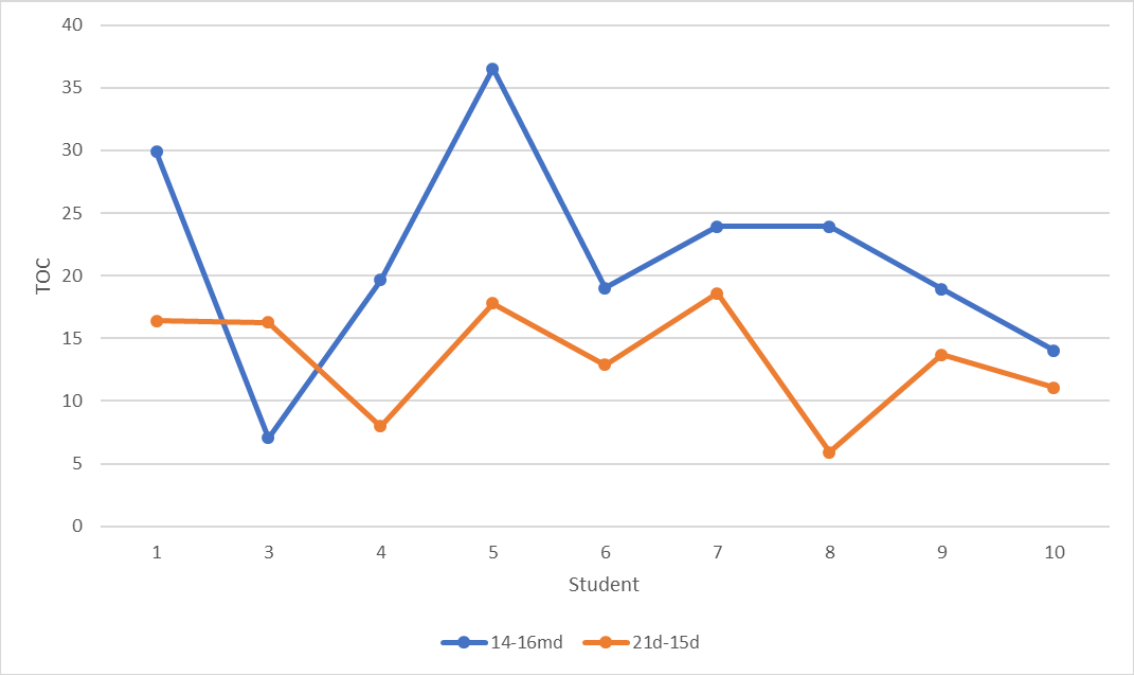

Figure 3. Chart describing the average convergence angles for the two FPD. Data from student nr 2 was excluded due to diverging angles.