Original Article

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Dentistry Section

In vitro Evaluation of the Accuracy of Seating Cast Metal Fixed Partial Denture on the Abutment Teeth with Varying Degree of Convergence Angle

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ABSTRACT

Background: The prime goal of a diligent prosthodontist is to obtain adequate marginal fit while restoring lost tooth structure. The marginal fit of the restoration, in turn depends upon the geometrical morphology of the tooth preparation.

Objective: To determine the effect of varying degree of convergence angle on the marginal seating of the single crown, three-unit fixed partial denture and multiple-unit fixed partial denture with pier abutment.

Materials and Methods: Three dies, of same convergence angle, were placed in an arch form on a base. In this way, four arch forms were prepared for four different convergence angles i.e. 0^0, 6^0, 12^0, and 20^0. Five castings each were made for single crown, 3-unit fixed partial denture and multiple-unit fixed partial denture (FPD) with pier abutment for each convergence angle. The castings were seated on their respective dies and vertical marginal discrepancy was measured at four points for each casting with the help of an optical microscope.

Results: The results showed that 20^0 convergence angle showed better marginal seating of the single crown, 3-unit FPD as well as for the multiple unit FPD.

Conclusion: There was a possibility that the retention and resistance may be compromised with 20^0 taper. Hence 12^0 taper is suggested for crowns and fixed partial denture retainers as the marginal discrepancy is reasonable and retention and resistance is optimum. There was a high statistical significant difference in the values obtained for the different convergence angles.

Keywords: Crown fit, Marginal seating, Marginal fit, Pier abutment, Single crown

INTRODUCTION

The design of tooth preparations can have an effect upon the success of individual restorations [1]. Restoration of the lost tooth structure with adequate marginal fit has been the goal of a conscientious prosthodontist. The term angle of convergence can be applied to denote the respective relationship between the two opposing walls of a preparation [2]. The convergence angle is valuable to visualize preparation walls, prevent undercuts, compensate for inaccuracies in the fabrication process, and permit more nearly complete seating of restorations during cementation [3].

In fixed prosthodontics, the interface between the restoration and the tooth is evident as the weakest link [4]. Marginal adaptation is one of the most significant factors influencing the clinical acceptability of the cast restoration [5]. It is a critical parameter as the dissolution of the luting agent and the inherent roughness may result in secondary caries. This loss of the underlying tooth structure will lead to the failure of the restoration [6]. Also, lack of adequate fit is potentially detrimental to the supporting periodontal tissues [7]. Attempts are made by the clinician to compromise the fit of the restorations by occlusal and internal adjustments leading to a threat to the cement-margin failure [8].

Tylman said that "it is apparent that every effort should be made to approach parallelism not exceeding "2^0 to 5^0 gingivocclusally" [9], whereas Johnston recommended "5^0 to 7^0 parallelism" [10]. Numerous studies have been done to evaluate the marginal fit of single crowns with different tapers but not many studies have been done to evaluate the taper which provides a better marginal adaptation for multiple unit castings. Hence, this study was carried out to verify the marginal fit of single crown, three-unit FPD and multiple-unit FPD with pier abutment with different degrees convergence angles.

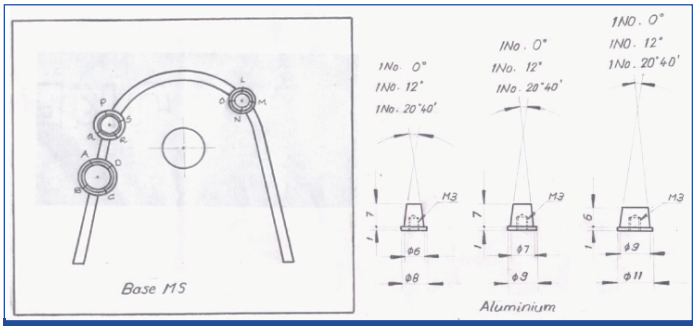
MATERIALS AND METHODS

The present study was a prospective study, conducted over a period of 3 years at A.B. Shetty Memorial Institute of Dental Sciences, Mangalore, Karnataka, India.

Description of Master Die

Three metal dies having the same convergence angles were made of aluminum. These dies were placed on an iron square block with the help of threaded retainer shaft in the position of first molar and first premolar on one side of the arch and canine in cross-arch relation. In the same way, four arch forms were made, each arch form having three dies (in the position of first molar and first premolar on one side of arch and canine in cross-arch relation), with the dies on each arch form having similar convergence angle. [Table/Fig-1] depicts schematic representation of the dies.

The dies for the molars had the diameter of 9 mm at the finish line and the height of 6 mm. The dies for the premolar had the diameter of 7 mm at the finish line and the height of 7 mm. The dies for the



[Table/Fig-1]: Schematic representation of the dies

canine had the diameter of 6 mm at the finish line and the height of 7 mm. Each die had a 1 mm 90^0 shoulder finish line. The dies with 0^0, 6^0, 12^0, and 20^0 convergence angles were mounted on the four arch forms.

Custom made moulds were fabricated of aluminum for each die in such a way that there was a uniform spacing of 1mm between the die and the mould. This was done to obtain standardized wax patterns. It is important that the copings be standardized so that no observed changes could be attributed to difference in contour, collar size or thickness of the coping. The dies with 0^0, 6^0, 12^0, and 20^0 convergence angles and the corresponding moulds are shown in [Table/Fig-2-5] respectively.

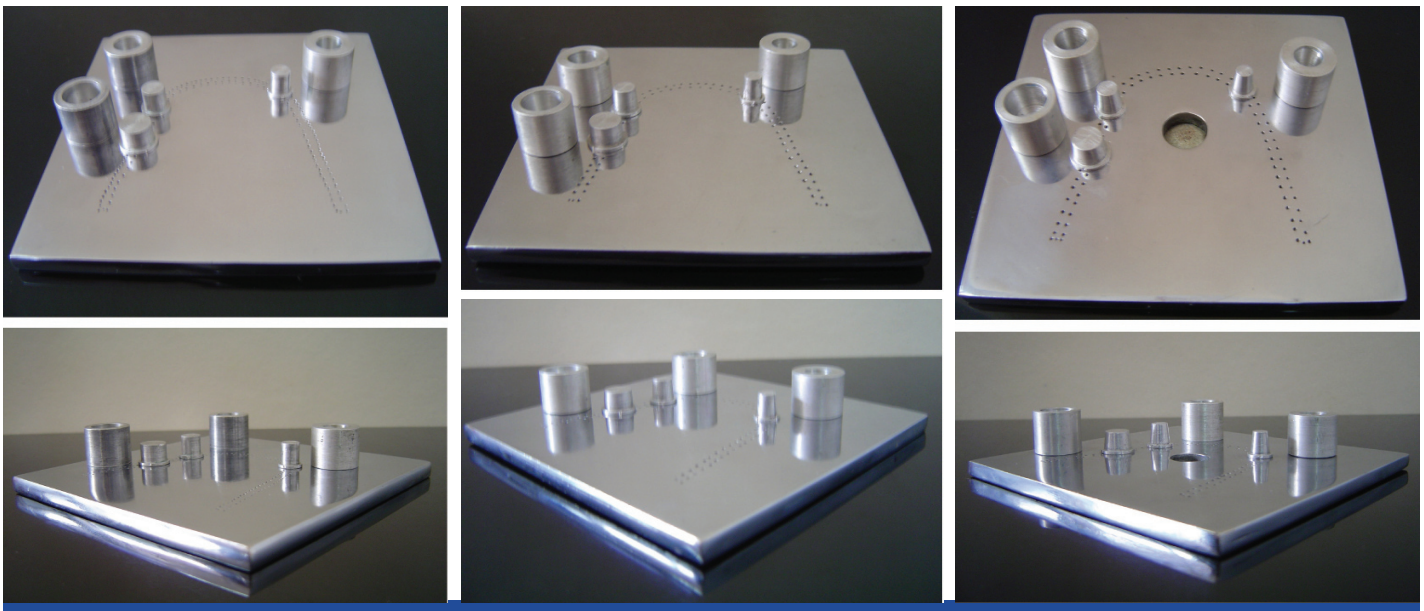
Wax Pattern Fabrication

To fabricate the coping wax patterns, type II inlay wax (Unident, India) was used. Die lube (Dentecon. Inc, Los Angeles, CA) was used as a wax separating agent on the inner aspect of the mould. Molten inlay wax was poured into the mould, and the die was seated in the mould. After cooling, the wax pattern was carefully separated from the mould. Excess wax was removed and the margins were burnished to ensure that they would be closely adapted. A 2.0 mm diameter (12-gauge) wax sprue (Schuler-Dental GmbH And Co. KG., Johannesstraße 6-8, D-89081 Ulm, Germany) was attached at a 45^0 angle to the occlusal surface of each wax pattern.

The sprue formers length was adjusted so that the pattern was 6.0 mm from the end of the ring, when kept in place. The point of attachment was flared and not restricted to decrease porosity and increase mould filling. Five wax patterns were prepared for single full veneer copings on molars; five wax patterns were made by joining the copings at the position of the molar and the premolar with the help of a connector of 2 mm diameter to form a three-unit FPD; and five wax patterns were made by joining the wax patterns at the position of the molar, the premolar and the canine with the help of connectors of 2.6 mm in diameter to form a multiple-unit FPD with a pier abutment, for each convergence angle.

Investing the Wax Pattern

Each wax pattern was immediately invested (Deguvest GF, Degussa, Germany) after marginal refinement to minimize distortion. Casting rings (Degussa, Germany) of the size no. 3 and no. 5 were lined with one non-overlapping layer of cellulose ring liner (Degussa, Germany), which was maintained 3 mm below the top of the ring,



[Table/Fig-2]: Dies with 0^0 convergence angles and the corresponding moulds **[Table/Fig-3]:** Dies with 6^0 convergence angles and the corresponding moulds **[Table/Fig-4]:** Dies with 12^0 convergence angles and the corresponding moulds

[Table/Fig-5]: Dies with 20^0 convergence angles and the corresponding moulds **[Table/Fig-6]:** Castings of single crown, three-unit fixed partial denture and multiple-unit fixed partial denture **[Table/Fig-7]:** Photomicrograph showing marginal discrepancy

all ring liners were wet when used. A 6mm distance was provided between the margin of the crown and the top of the casting ring. Surfactant (Lubrofilm, Dentaurum, GmbH & Co. KG Turnstraße 31 D-75228 Ispringen) was sprayed on the wax pattern and allowed to dry for 3 minutes. Investing was then carried out, in which the investment was hand mixed for 20 seconds, followed by 90-second mechanical mixing under vacuum (Multivac 4, Degussa). The wax patterns were invested with a camel-hair brush and allowed to bench set for 30 minutes. All base formers were then removed.

Wax Pattern Elimination and Casting

Conventional lost wax technique (Kavo EWL Type 5630) was carried out for complete elimination of wax from the moulds. The moulds were placed in a cold furnace and heated up to 250^{0}C at a rate of 5^{0}C/min and the temperature was maintained for 30 minutes. The mould was then heated to a final temperature of 950^{0}C at the rate of 7^{0}C/minutes and maintained at that temperature for 30 minutes. All casting procedures were carried out in induction casting machine (Degutron, Degussa, Germany) to make nickel chromium copings (Wirolloy, Bego). All castings were cooled to room temperature before removal from casting ring. After the castings were removed, they were sandblasted (Superstrahl, Degussa) with 50 µm Al_2O_3 at 30 psi pressure at a distance of approximately 5 cm. All sprues were removed with an abrasive disk, cleaned in ultrasonic cleaning solution (Sonorex Super RK102P, Bandelin) for 15 minutes, rinsed and dried. [Table/Fig-6] depicts the castings of single crown, three-unit FDP and multiple-unit FDP.

Method of Measurement

While the castings were seated on their respective dies, indentations were made, with the help of a rotary instrument, at four points on each die, i.e. mesiobuccal, distobuccal, distolingual and mesiolingual. These indentations were used as the reference points to check for marginal fit. An optical microscope (Labomed) with a filar eyepiece was used at 100x magnification to record the measurements of the vertical marginal discrepancy. [Table/Fig-7] represents a photomicrograph showing marginal discrepancy.

A transfer block was constructed to hold the castings for measuring the marginal discrepancy in the optical microscope. The castings in place were embedded in a layer of softened impression compound which was allowed to harden. When the dies were removed from the base, the castings remained with the transfer block maintaining the same relationship on the apparatus.

STASTICAL ANALYSIS

The data was subjected to appropriate statistical analysis. The mean values obtained for discrepancy were compared using t-test and ANOVA.

RESULTS

The results of the present study are presented in [Table/Fig-8,9]. [Table/Fig-8] depicts the mean values obtained for discrepancy in marginal fit observed for single crown, three-unit FDP and multiple-unit FDP with pier abutment. These mean values were obtained by analyzing the mean values obtained at four points on each die, i.e. mesiobuccal, distobuccal, distolingual and mesiolingual.

The results of the marginal discrepancy obtained for the single crown denote that the marginal discrepancy was minimum for 20^0 convergence angle, i.e. 29.482 µm and was maximum for 0^0 convergence angle, i.e. 36.395 µm. Similar results were observed for three-unit FDP. The discrepancy for molar was 26.236 µm and that for premolar was 24.061 µm for 20^0 convergence angle which was much less than the discrepancy seen for 0^0 convergence angle where the discrepancy for molar was 35.720 µm and that for premolar was 35.453 µm. Multiple-unit FDP with a pier abutment also revealed minimum discrepancy values for 20^0 convergence angle and maximum discrepancy values for 0^0 convergence angle. The discrepancy for molar was 29.467 µm, for premolar was 29.519 µm and that for canine was 27.633 for 20^0 convergence angle which was much less than the discrepancy seen for 0^0 convergence angle where the discrepancy for molar was 42.900 µm, for premolar was 42.230 µm and that for canine was 42.47.

[Table/Fig-9] depicts the statistical analysis of variance applied on the means of the vertical marginal discrepancies for single crowns, three-unit FDP and multiple-unit fixed partial denture with pier abutment. These included the comparison of the vertical discrepancy between the units of 20^0 convergence angle with the units of 0^0, 6^0, and 12^0 convergence angles. A very high statistically significant difference (p<0.001) was observed for the vertical marginal discrepancy of the single crown, three-unit FDP and multiple-unit fixed partial denture with pier abutment.

Convergence angle		Single crown	Three-unit fixed partial denture		Multiple-unit fixed partial denture with pier abutment		
			For molar	For premolar	For molar	For premolar	For canine
0^0	Mean	36.395	35.720	35.453	42.900	42.230	42.477
	SD#	0.9891	0.6975	0.8530	0.8250	0.7102	0.6665
6^0	Mean	33.990	34.758	34.976	42.564	42.084	42.805
	SD#	0.5924	0.8543	0.6178	0.5761	0.6917	0.4014
12^0	Mean	32.406	32.121	30.630	38.659	36.924	38.129
	SD#	0.8341	0.6175	0.9915	0.5992	0.6672	0.4957
20^0	Mean	29.482	26.236	24.061	29.467	29.519	27.633
	SD#	0.8325	0.9218	0.9214	1.4144	1.6175	0.6154

[Table/Fig-8]: The mean values and standard deviation of discrepancy in marginal fit noted for single crowns, three-unit fixed partial denture and multiple-unit fixed partial denture with pier abutment (discrepancy values in µm)
#SD: Standard Deviation

Convergence angle	Single crown		Three-unit fixed partial denture				Multiple-unit fixed partial denture with pier abutment					
			For molar		For premolar		For molar		For premolar		For canine	
	t-value	p-value	t-value	p-value	t-value	p-value	t-value	p-value	t-value	p-value	t-value	p-value
0^0 and 20^0	23.914	0.001*	23.218	0.001*	31.156	0.001*	36.688	0.001*	31.207	0.001*	35.725	0.001*
6^0 and 20^0	10.739	0.001*	13.542	0.001*	29.156	0.001*	29.127	0.001*	35.781	0.001*	92.348	0.001*
12^0 and 20^0	11.096	0.001*	11.347	0.001*	21.704	0.001*	26.761	0.001*	18.927	0.001*	59.543	0.001*

[Table/Fig-9]: Statistical comparison between mean values of discrepancy in marginal fit of single crown, three-unit fixed partial denture and multiple-unit fixed partial denture with pier abutment, with four different convergence angles
*Very highly significant statistically

DISCUSSION

Convergence angle is mainly associated with the retention, resistance and the marginal fit of the FDP restoration [11]. The marginal fit of any restoration is vital for its long term success [12]. Geometry of the tooth preparation, including the type of finish line and the degree of taper is an important factor in obtaining close marginal adaptation [13]. Dodge et al., concluded that the resistance form is more sensitive to changes in convergence angle [14]. Also, they reported that there is no significant difference in retention values between preparations with 10^0 total convergence angle as compared with 16^0 convergence angle. Wilson et al., concluded that the crowns cemented on preparations with a convergence angle between 6^0 and 12^0 had the highest retentive values [15]. Many researchers have stated that parallelism of axial walls is important in retention of the crowns; however, parallel walls are impossible to create in the mouth without producing preparation undercuts [16,17].

Poor marginal adaptation is one of the reasons for the failure of crowns and FDP [18]. The reason for failure may be microleakage which may further lead to secondary caries [19]. Also, with poor marginal fit, the plaque accumulation potential of the fixed partial restoration increases leading to periodontal breakdown [20]. Goodacre et al., concluded that the reason for failure of single crown was periodontal disease (0.6%) and caries (0.4%) [21]. The reason for failure of fixed partial denture was caries (18%) and periodontal disease (4%). Walton et al., concluded that there was no apparent relationship between the span of prosthesis and its length of service [22]. Thus, the present study was undertaken to determine the marginal fit of single crown, three-unit FDP and multiple-unit FDP with pier abutment with different convergence angles.

In this study, four convergence angles were used, i.e. 0^0, 6^0, 12^0, and 20^0 in order to determine as to which convergence angle gives a better marginal fit. These convergence angles were selected for the study as these have been advocated and used by most of the authors in the previous literature. The dies with the convergence angle of 0^0 had all the axial walls parallel; 6^0 had 3^0 taper on each axial wall; 12^0 had 6^0 taper on each axial wall; and 20^0 had 10^0 taper on each axial wall. The machined metal dies enabled to accurately control the variables of preparation design, degree of convergence angle and the finish line dimensions, which was a 1 mm 90^0 shoulder finish line. The metal dies were placed at the position of molar and premolar on one side of the arch and canine in cross arch relation, in order to simulate the arrangement of natural teeth in the oral cavity. In this study, the marginal fit was evaluated for the single crowns, three units fixed partial denture as well as multiple unit fixed partial denture with a pier abutment.

The results of the marginal discrepancy obtained for all the units assessed in our study i.e. for single crown, 3 unit FDP and multiple unit fixed partial denture with a pier abutment, denote that the marginal discrepancy was minimum for 20^0 convergence angle, and was maximum for 0^0 convergence angle. Thus, as the convergence angle increases from 0^0 to 20^0, the accuracy of marginal fit also increases which indicates that there is more complete seating of the single crown with 20^0 convergence angle. Further, the statistical comparison of the each of the three units assessed in our study, a very highly significant difference ($p<0.001$) was observed when 20^0 convergence angle was compared with other convergence angles i.e. 0^0, 6^0 and 12^0.

For the multiple unit FDP with a pier abutment, it has been theorized that the pier abutment acts as a fulcrum, causing forces that are transmitted to the terminal abutments and leads to the failure of the weaker abutment [23]. Construction of a one piece multiple unit FDP has distinct advantages like maximum strength of the rigid connector and elimination of the soldering procedure which may be the cause of failure in due course of time. Garlapo et al., reported that four unit castings were possible without appreciable warpage [24].

From the results, it can be seen that 20^0 convergence angle gives better marginal fit than any other convergence angle. However, Tylman advocated the convergence angle of $2\text{-}5^0$ considering the prime factor retention [9]. Further, according to Woosley and Matich [25] proximal grooves are effective partially to increase the resistance of single crown; and also, Reisbick and Shillinburg state that proximal grooves did not improve retention of single crowns [26]. According to Mack, unless special intraoral jigs are used, it is not possible to prepare teeth with a taper less than 12^0 [27].

Thus, the above discussion implies that it is not known as to what is the minimum required retentive figure, clinically. But at the same time it is a well known fact that most teeth are prepared with tapers in excess of 12^0 and they still function adequately [28]. Moreover, there is a minimum difference between the marginal discrepancy of 12^0 and 20^0. Hence, without compromising the retention and resistance, it is recommended to provide a maximum axial wall taper of 12^0 for crowns and FDP prosthesis.

LIMITATIONS

The present study has certain limitations, some of which are stated as follows: this is an *invitro* study and hence the exact resemblance of the oral cavity environment could not be incorporated in the study, though effort was made to do so by arranging the dies in an arch form and selecting the dimensions of the teeth as that of the ideal natural teeth; also the convergence angles were studied only with respect to the marginal fit of the crowns and fixed partial dentures, the resistance and retention was not taken into consideration. Hence, a further *invivo* research is recommended to compare the convergence angle with the retention, resistance and the marginal fit of the crowns and fixed partial dentures.

CONCLUSION

From our study, the following conclusions could be drawn: the 20^0 convergence angle showed the minimum marginal discrepancy whereas 0^0 convergence angle exhibited maximum marginal discrepancy. Statistical analysis showed that the difference between the four convergence angles for single crowns, three unit FDP, and multiple unit FDP with pier abutment was very highly significant. From the discussion, it can be concluded that though 20^0 convergence angle gives better marginal fit, it may compromise the retention and resistance of the crowns and FDP restorations. As there is minimum difference between the marginal discrepancy of 12^0 and 20^0, hence, without compromising the retention and resistance, it is recommended to have a maximum axial wall taper of 12^0 for crowns and fixed partial denture prosthesis. Further research should be conducted to determine the effect of convergence angle on the marginal fit as well as the retention and resistance of fixed partial restoration. Also instead of metal dies, natural teeth should be considered for the future study.

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