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Comparative evaluation of supplementing retention through crown and abutment modification for a tooth with inadequate retention and resistance form – An Invitro study

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Abstract

Tooth preparations with inadequate retention and resistance form often contribute to the dislodgment of complete cast crowns. Existing dental anatomy often limits the dentist in modification of crown length and diameter, but occlusal convergence angle can be reduced to increase resistance form. The auxiliary retentive features like grooves and boxes have been effective in increasing the surface area and reducing the rotational radius, thereby increasing the retention and resistance of crowns. This study was designed to determine whether retention of such crowns can be increased without remaking the crown or by extensively modifying the tooth preparation. Horizontal grooves were made around the circumference of the internal crown surface and the external surface of the metal die, the control being the unaltered crown and the die. The crowns were cemented and subjected to a tensile force until they were dislodged. The data were subjected to a 2-way ANOVA to determine the significance of the differences between the crowns and

the dies, and 2*t* tests were used to compare each crown/ die combination to the control (a=.05).

The mean retention was significantly higher when 1 horizontal groove was placed inside the crowns (*P*<.001). Placing 1 groove in the metal die or in both the crown and die was not significantly more retentive. Grooves placed into the crown were as effective as or more effective that grooves placed into the tooth or the die.

Keywords: Retention form, resistance form, auxiliary features, total occlusal convergence.

Introduction:

Optimal retention and resistance form for extracoronal restorations have been established on the basis of analysis of the geometric configuration of tooth preparations including aspects such as convergence [1-3], surface area of the preparations [4,5], internal surface roughness of the castings [6,7], auxiliary grooves [8,9], tooth surface preparation [10,11] and type of cement used [1,12]. Lack of retention has been shown to be a common cause of fixed prosthesis failure [1,13]. The purpose of this study was to determine whether adding horizontal grooves to the internal surface of the crown and/or tooth preparation would improve retention of a metal complete crown.

Methodology

Forty (40) cast metal complete crowns, divided into 4 groups of 10, were fabricated to be slightly loose in their internal adaptation to metal dies with an inadequate tooth preparation. Metal dies were prepared using a milling machine with a 10degree taper cutting tip resulting in a 20degree total occlusal convergence. A deep chamfer finish line of 0.3mm was prepared. The completed tooth preparation possessed an occlusocervical dimension of 2.5mm, an internal faciolingual dimension of 9.8mm. The occlusocervical and faciolingual ratio was 0.26 when the external tooth dimension was used in the ratio calculation which did not meet the minimally acceptable value proposed for molars (fig 1).

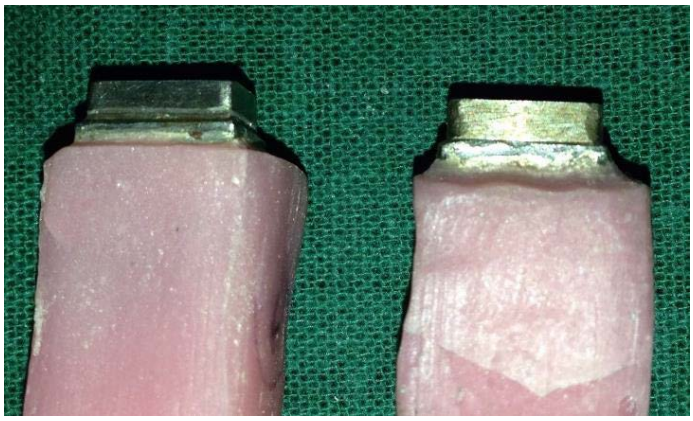


Fig.1**:** Altered and unaltered dies

The tooth preparation was judged to lack adequate resistance and retention form according to recently proposed criteria. On the master die addition silicone putty and light body impression was made and the die was poured with die stone (fig 2). The stone die was scanned by CAD unit (fig 3) and wax patterns were milled with the help of CAM unit to achieve standardization of crowns (fig 4). On the occlusal surface of the wax pattern a loop was attached for the tip of universal testing machine. These wax patterns were cast in Ni-Cr base metal alloy (fig 5).

Fig. 2: Metal dies duplicated in stone for CADCAM scanning

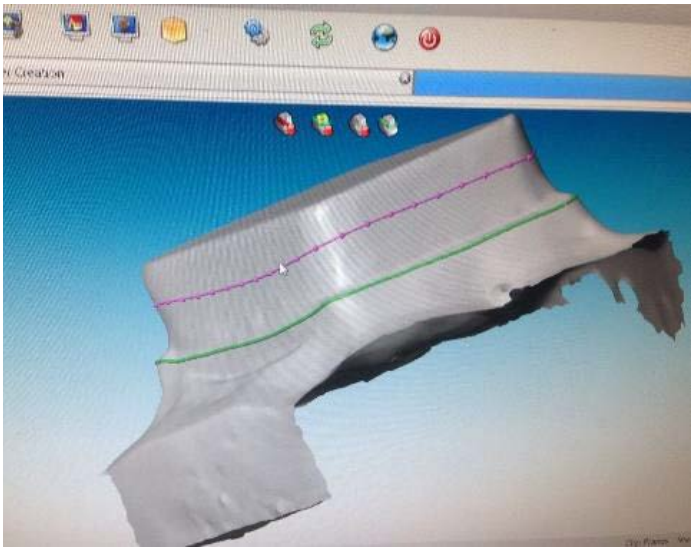


Fig. 3: CAD scanning of the stone die

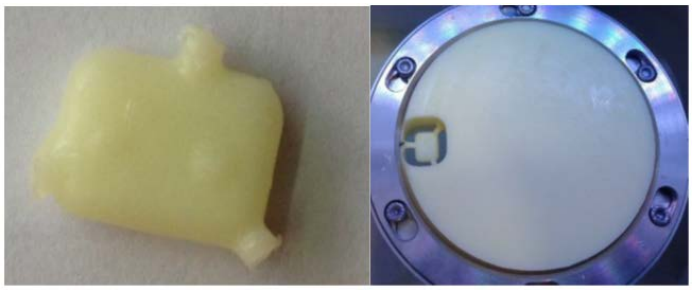


Fig. 4: CAD milled wax pattern

Fig. 5: Each Die with two crowns

Control group 1: Consisted of unmodified crown and dies. The fit of each crown was verified and a disclosing material was used to identify areas that prevented complete seating of the restorations. The intaglio surfaces of the castings were adjusted to allow complete seating of the crowns. The crowns were subjected to airborne particle abrasion before cementation. All the crowns were cemented with glass ionomer cement following the manufacturer's instructions and by using finger force for 60 seconds to seat the crown. The cement was allowed to set in a dry field for 10 minutes and then the crown/die combinations were placed in water for at least 24 hours (fig.6).

Fig.6: Luted specimens immersed in water

The cement film thickness was controlled by marking a spacer on the scanned dies with the help of CAD software. The crowns were removed from the dies with a cobalt-chromium alloy device designed to create an in-line tensile force on the cement junction. A 6.35 mm twisted steel cable was connected to the end of the device to allow for adjustment and an equal pull. The cable of the device was held firm by the lower jaw clamp of the tensile testing machine, while the die and crown, inserted in the device, were attached to the chuck of the upper mobile member of the machine (fig.7).

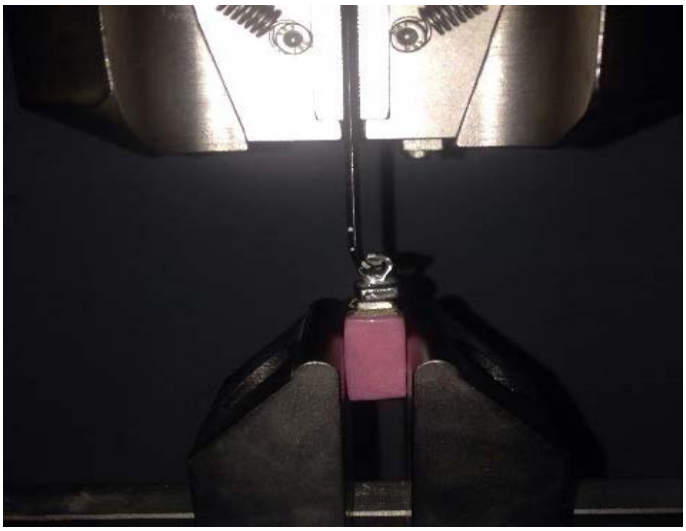


Fig. 7: Testing for retention

The tensile force (N) needed to remove the crowns was measured with a universal testing machine drawn at a rate of 0.5mm/min.

Group 2: This group consisted of ten dies with circumferential grooves of 0.5 mm deep were placed 1mm from margin and ten crowns were fabricated as previously described. The crowns were again disclosed and internally adjusted for complete seating. These crowns were cemented with glass ionomer cement mixed according to the manufacturer's instructions and dislodged using universal testing machine and the dislodging force recorded.

Group 3: This group consisted of ten crowns with circumferential groove (C1) prepared free hand on the internal side with the edge of a #37 inverted cone carbide bur approximately 1mm from the margin and the die was unaltered. The crowns were cemented following the same protocol and measurement of dislodging forces was done.

Group 4: This group consisted ten specimens with a circumferential groove on both the crown and die. The crowns were cemented using the same protocol and measurement of dislodging forces was done.

Results

The dislodgement of crown forces was obtained through the Universal testing machine and analysed using the ANOVA test followed by post hoc Tukey's test. It demonstrated that the values observed by placing circumferential groove on the internal side with the edge of a #37 inverted cone high speed carbide bur approximately 1mm from the margin with the die unaltered internal auxiliary retentive features like grooves and boxes on the original preparation design at the cervical area were significantly higher than the control group. (Table–1), (Table–2)

Table1: comparison of tensile strength between the four study groups

	N	Mean	Std. Deviation	ANOVA	
				F value	p-value
Group 1	10	254.50	53.05	30.19	<0.001*
Group 2	10	413.50	73.42		
Group 3	10	586.30	96.22		
Group 4	10	447.70	84.54		

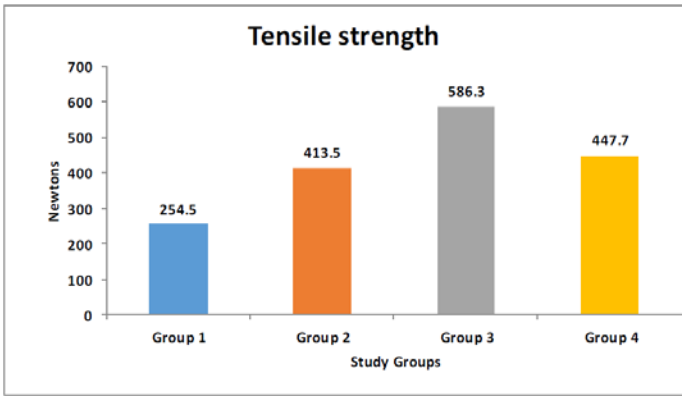
Table2: Pairwise comparison of tensile strength among the four study groups

(I) Group	(J) Group	Mean Difference (I-J)	95% Confidence Interval		p-value
			Lower Bound	Upper Bound	
Group 1	Group 2	-159.00	-253.48	-64.52	<0.001*
	Group 3	-331.80	-426.28	-237.32	<0.001*
	Group 4	-193.20	-287.68	-98.72	<0.001*
Group 2	Group 3	-172.80	-267.28	-78.32	<0.001*
	Group 4	-34.20	-128.68	60.28	0.76(NS)
Group 3	Group 4	138.60	44.12	233.08	0.002*

There was a significant difference in mean scores among the groups for maximum force and displacement. Post hoc test revealed that the control group had significantly lower maximum force than group 2, 3 and 4, for maximum displacement.

The tensile forces required for the mechanical dislodgement of crowns recorded by The Universal testing machine showed significant increase in retention in group 3 compared to group 1. The group 1 exhibited the least test values in the test groups and there was a little variation in the retention between group 2 and group 3, but was not statistically significant. (chart-1)

Chart 1



Discussion

This study tested the tensile force required to dislodge a crown from a die. The data support the rejection of the null hypothesis that altering the crown and die would not increase retention. The looser fit was considered to represent most clinical situations where a crown has been dislodged from an ideal preparation. These tests demonstrated a cohesive failure of the cements as cement components were found on both the crown and tooth preparation surfaces. Mastication is not a process that places forces purely along the long axis of a prepared tooth.

The Cement (Fuji Plus) used in this experiment had a tensile strength of 25MP a (data from GC America Inc, Alsip, Ill). It should also be noted that, shorter clinical preparations, poor tooth foundation and preparation with convergence angles of 20 degrees or greater, shift the cement interface from compression to shear resulting in a greater possibility of failure of the cement interface through cohesive fracture. Also, clinically many other factors such as bruxism, types of food masticated, amount of saliva in the mouth and number of teeth remaining may be involved in dislodging a crown.

In this study, the grooves on the crowns and the dies were placed approximately in the same positions so that they are opposite to each other when cemented together. The theory behind this procedure was that the alignment of the 2 grooves would place some of the cement interface under compression. Fabricating opposing grooves in the mouth is possible; however clinical experience has shown that most dislodged crowns do not have enough tooth surface area to accommodate 2 grooves. This research shows that a single groove in the crown is as effective in increasing the retention, as single opposing grooves and grooving the internal surface of the crown may be the most efficient method of obtaining additional retention even if all other parameters may not stay the same.

Even though 2 to 5 degrees has been taught for years as a standard for preparation taper and is a foundation p rinciple of fixed prosthodontics, it is not consistent with reality. Owen'o states, most teeth are prepared with tapers in excess of 12 degrees and still function adequately. It is not known what retentive figure is minimally required. Determination of adequate taper is more logically based on principles of resistance. The resistance form is also said to be a more general principle and if preparation has resistance form it will have retention, whereas the reverse is not true. To be clinically acceptable the preparation must resist rotation in all directions, buccal, lingual, mesial and distal.

Weed and Baez proposed a different method of assessing resistance from using a circle centered on the margin of the opposing side. Their concept was that if the preparation wall falls inside this arc, then it lacks resistance form [6]. Parker et al suggested that resistance form at each point on the axial wall could be evaluated by

drawing an arc of the circle centered on the opposite margin [13]. The point on the preparation has resistance form if the direction of arc is in to the preparation.

The geometric form might have had some restrictive effect on the setting expansion of the investment. For a given alloy, the inherent casting shrinkage is determined only by its coefficient of thermal expansion and its solidus temperature, and the actual or observed casting shrinkage is decreased by a varying amount depending on the size and shape of the casting [14]. The alloy's modulus of elasticity, $25X10^6$ psi, its Vickers hardness No340 such that it could with stand the forces to which the dies would be subjected during loading of cast restorations[15].

In this study, the wax was applied directly onto the metal dies. It has been shown that the degree of adaptation or misfit of a crown that has been waxed onto a metal die is less than for a crown waxed on a stone die. Metal dies were used to avoid fracture or distortion of the die during testing. Alternatively, the crowns in the current study could have been duplicated in the form of stone dies and the waxing performed on stone dies.

The rationale for using base metal alloy in this study was its high compressive strength, which allows the metal to resist deformation if excessive forces are applied. Regardless of the inherent limitations of any casting procedure or technical modifications that could offer an improved internal adaptation, there will always be a space between a crown and a die. This space will be occupied by the cement, based on this observation, multiple authors have indicated that this film of cement is the key to determining the resistance of a crown.

Conclusion

Within the limitations of this study, the following conclusions are offered relative to the effectiveness of tooth/crown preparation modifications on the retention form of the teeth prepared with 2.5 mm of occlusocervical dimension, 20degrees of TOC and an occlusocervical / faciolingual dimension ratio below 0.4. Placing circumferential groove in the internal surface of crown 1mm away from the margin significantly enhanced the retention form.

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