Original Article

Effect of ring liner and casting ring temperature on the dimensional changes in morphologic cast posts: *An in vitro* study

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Prosthodontic treatment of an endodontically treated tooth poses a challenge to the practitioner. Endodontic therapy has provided a solution to retain mutilated teeth. Coronoradicular reconstruction in the form of cast post and core is used as a method to provide retention and resistance form to the restoration. Endodontically treated teeth are dessicated, inelastic and brittle& have lower resistance to caries. Their inability to form secondary dentin makes them weak and susceptible to fracture. To prevent fracture and support crown and bridge, reinforcement in the form of intraradicular devices is being used. A cast post is one such method. Vertical and horizontal root fractures can occur as a result of excessive removal of tooth structure during root canal treatment, dowel placement or inceasing the width of the dowel. A cast post and core should fit passively in the canal. Even a minimally oversized post can lead to transfer of stresses to the canal walls and increase the risk of root fracture. Therefore it is necessary to ensure that there is passive fit of the post and core. Shrinkage of the mould cavity is desired during the casting process to allow a passive fit. The effect of lined and unlined rings in the dimensional behaviour of the investment during setting and subsequent heating has been investigated and it is shown that casting made of unlined rings are undersized.

Key words: metallic posts, cast posts, ring liner

INTRODUCTION

Conservation of the tooth structure and restoration of esthetics and occlusion are the primary objectives in dental practice.

Endodontic therapy has provided a solution to retain mutilated teeth. However, endodontically treated teeth are dessicated, inelastic and brittle & have lower resistance to caries. Their inability to form secondary dentin makes them weak and susceptible to fracture.[1-4] To prevent fracture and support crown and bridge, reinforcement in the form of intraradicular devices is being used. A cast post is one such method, which recognizes 2 functions.

- Protects the weakened tooth from concentrated internal stresses and tooth fracture and
- Provides adequate retention for a restoration to function within various dentition.

A cast post should fit passively and drop in place when tried in the canal but also should resist rotation and rocking. If post and core does not fit properly, binding into the radicular structure may occur. In photoelastic studies active post engagement has led to high stresses and may increase the risk of fracture.[5-7] Therefore it is necessary to fabricate a slightly undersized cast post to allow for passive fit and cement placement.

The effect of lined and unlined rings in the dimensional behaviour of the investment during setting and subsequent heating has been investigated and it is shown that casting made of unlined rings are undersized.

The study was hence undertaken to evaluate the influence of ceramic ring liners and lower casting temperature of the metal ring on re dimensions of cast posts.

MATERIALS AND METHODS

An *in vitro* study was done to evaluate the effect of casting ring liner and casting ring temperature on the dimensional changes in cast costs.

Methodology

Preparation of the master post

40 acrylic resin post patterns were used in the study. Patterns were fabricated from a master post and core, which was indegeniously prepared in the following manner. A bur shank was used as a post. 2 notches

were prepared in the shank with a rotary instrument. One notch was placed 2 mm from one end of the post (tip) while the other notch was placed 5 mm from the other end. The post measured 12 mm. An acrylic resin core was fabricated over the post and trimmed to the dimensions of 5 mm x 5 mm.

Preparation of acrylic resin patterns

The post and core pattern was impressed with vinyl polysiloxane (President, Coltene Corp. Switzerland) to create a mold. After removal of the pattern acrylic resin (GC Pattern resin, GC Corp, Tokyo, Japan) was poured inside the mold with plastic syringe to fabricate a new acrylic resin pattern. All patterns were fabricated with the same polyvinyl siloxane impression mold. Measurements were made at both the notches with tool makers microscope (least count - 1 U) as the distance between the outer surface of the post and a tangent drawn to the notch, by one investigator before investing. Also the length between the notches was measured from their deepest point.

Preparation of cast posts

Patterns were divided randomly in groups of 10 posts each. For group 1, each pattern was sprayed with a surfactant (Debubblizer, Mizzy Inc). Excess surfactant was removed by tightly blowing air on the pattern. Each pattern was individually invested with 60 g of phosphate bonded investment (Supervest and special liquid and distill water (12.5 ml and 2 ml respectively) using manufacturers instructions. One layer of ceramic ring liner was used to line nickel based alloy casting rings leaving 6 mm of unlined ring at each end. The rings were then immersed in water for 15 seconds and shaken 5 times to remove excess water. The investment was mechanically spatulated under a guage vacuum of 90 kPa for 90 seconds and then poured in the metal ring at atmospheric pressure on a vibrator. All mixing and investing procedures were carried out at room temperature. The investment was allowed to bench set for 1 hour and placed in room temperature oven.

For group 2, the same steps as in group 1 were followed, except that no ceramic liner was used in the metal ring.

For group 3, the same steps as in group 1 were followed except that metal rings were heated to maximum temperature of 900°C for 30 minutes. Temperature was then decreased to 700°C and maintained for 30 minutes before casting. This heating protocol was suggested by the manufacturer to complete the instrument's high temperature chemical reactions.

For group 4, the same steps as group 3 were followed except that no liner was used.

Investing & casting variables

Groups	Ring liner	Burn out temperature	Temperature gradient	Second temperature	Rate of cooling	Final temperat
1	Yes	150°C	7°C	MA	NA	900°C
2	No	150°C	7°C	MA	NA	900°C
3	Yes	150°C	7°C	900°C	7°C	700°C
4	No	150°C	7°C	900°C	7°C	700°C

The investing and casting procedures were performed by a single operator. The castings were performed with induction casting machine using Nickel chromium alloy (Sankin). Casting rings were allowed to bench cool to room temperature. The cast posts were divested and sandblasted to remove investment debris (250μ alumina was used). Posts that showed casting irregularities at the notches were eliminated. The dimensions of cast posts were again measured with tool makers microscope. All metal posts were measured at the same time.

Statistical analysis

Mean and standard deviation was calculated for each group. The data was analysed with an analysis of variance (ANOVA) and a Turkey Studentized test. The level of significance was set at $P < 0.5$.

RESULTS

An *in vitro* study was carried out to evaluate the effect of ring liner and casting ring temperature on the dimensional changes in cast posts. The results of the study were:

1. A comparison of the mean change in width of the pattern and cast posts obtained by the four methods showed statistically significant results.

Mean Pretreatment values of pattern of notch A and B = 1.214 [Table 1]

The smallest dimensions were obtained in group 4 while largest dimensions were in group 1.

1.242 and 1.243	900°C with liner	Group 1
1.156 and 1.165	900°C without liner	Group 2
1.230 and 1.233	700°C with liner	Group 3
1.101 and 1.106	700°C without liner	Group 4

2. A comparison of the mean change in width when compared between the cast posts of all groups showed statistically significant results between all groups except group 1 and Group 3 ($P > 0.5$) for both notch A and B. [Table 2 & 3]
3. When compared the effect of liner against the effect of temperature the dimensional changes in width due to the presence of a liner are statistically significant. [Table 4]
4. A comparison of the mean change in length of the pattern and cast posts obtained by 4 methods showed statistically significant increase in length

5. A correlation between the width and length for each group showed a negative correlation for groups (2) and (4) [without liner]. Decrease in width resulted in increase in length for cast posts in groups (2) & (4).

Table 1: Mean measurements of width of resin patterns and cast posts at notches A and B for all four groups

Notch	Groups	Mean	SD	Unpaired *t*-test*	*P*-value	Significant
Notch A	Pretreatment	1.214	0.008	–	–	–
	900°C with liner	1.242	0.064	2.832	<0.05	S
	900°C without liner	1.156	0.023	13.274	<0.05	S
	700°C with liner	1.230	0.048	2.139	<0.05	S
	700°C without liner	1.101	0.018	30.517	<0.05	S
Notch B	Pretreatment	1.214	0.008	–	–	–
	900°C with liner	1.243	0.045	3.954	<0.05	S
	900°C without liner	1.165	0.021	12.282	<0.05	S
	700°C with liner	1.233	0.053	2.224	<0.05	S
	700°C without liner	1.106	0.034	18.582	<0.05	S

*Between Pretreatment measurements and stated group measurement.

NS, Not Significant; S, Significant.

Table 2: Comparison between measurements of width at notch A between pairs of all four groups

Notch	Groups	Mean	SD	Unpaired *t*-test*	*P*-value	Significant.
Notch A	900°C with liner	1.242	0.067	4.007	<0.05	S
	900°C without liner	1.156	0.023			
	900°C with liner	1.242	0.064	0.467	>0.05	NS
	700°C with liner	1.230	0.048			
	900°C with liner	1.242	0.064	6.717	<0.05	S
	700°C without liner	1.101	0.018			
	900°C without liner	1.156	0.023	4.367	<0.05	S
	700°C with liner	1.230	0.048			
	900°C without liner	1.156	0.023	5.829	<0.05	S
	700°C without Liner	1.101	0.018			
	700°C with liner	1.230	0.048	7.895	<0.05	S
	700°C without liner	1.101	0.018			

*Between two stated group measurement.

NS, Not Significant; S, Significant.

Table 3: Comparison between measurements of width at notch B between pairs of all four groups

Notch	Groups	Mean	SD	Unpaired *t*-test*	*P*-value	Significant.
Notch B	900°C with liner	1.243	0.045	4.946	<0.05	S
	900°C without liner	1.165	0.021			
	900°C with liner	1.243	0.045	0.4600	>0.05	NS
	700°C with liner	1.233	0.053			
	900°C with liner	1.243	0.045	7.585	<0.05	S
	700°C without liner	1.106	0.034			
	900°C without liner	1.165	0.021	3.756	<0.05	S
	700°C with liner	1.233	0.053			
	900°C without liner	1.165	0.021	4.611	<0.05	S
	700°C without liner	1.106	0.034			
	700°C with liner	1.233	0.053	6.304	<0.05	S
	700°C without liner	1.106	0.034			

*Between two stated group measurement.

NS, Not Significant; S, Significant.

RESULTS

[Table l] Mean measurements of width of resin patterns and cast posts at notches A and B for all four groups.

DISCUSSION

With advances in field of endodontics a practitioner can expect good prognosis for endodontically treated teeth. However special techniques are needed to restore such a tooth. Usually a considerable amount of tooth structure is lost because of caries, endodontic treatment and placement of previous restorations. However when substantial amount of coronal tooth structure is missing, a cast post and core is indicated.

Although prefabricated posts have these advantages, the customised cast post and core possesses superior adaptation to the root canal. The canal is altered to fit the prefabricated posts while the customised casting is made to fit the tooth.

In a study with freshly extracted mandibular premolars Chan & Byrant[18] determined that cast gold dowels and core demonstrated a significantly lower mean failure rate than amalgam or composite cores or *cemented* parapost.

The seating of cast post in root canal should be passive, otherwise the potential for root fracture may increase. Dowels can produce high stress in dentin. Standlee et al[5,7] reported that stresses induced during installation and loading of actively seated dowels exceeded those of passively cemented dowels. Pressure generated during luting of cast posts to tooth structure may also be responsible for these stresses.

Mattison[16] and Mattison and von Fraunhouf[17] in two dimensional, photoelasticity to compare stresses generated upon loading of cast gold endodontic posts of different diameter. The study suggested that the diameter of the post with a core affects the magnitude of stresses. Stress generally increases as post diameter increases and as vertical load increases. The authors advised restricting the diameter of the post, especially when the patient exerts large occlusal forces. They advocated the use of smaller diameter posts as these reduce dentinal stresses, conserve tooth structure and

Table 4: Comparison of measurements of groups 1 + 3 and 2 + 4 for notches A and B

Mean		SD	Unpaired t-test*	P-value	Significant
900°C with liner and	1.236	0.055	2.360	<005	S
900°C with liner	1.194	0.056			
700°C without liner					
900°C without liner and	1.238	0.049	7.220	<005	S
900°C without liner	1.136	0.041			
and 700°C with liner					

NS, Not Significant; S, Significant.

possibly aid operative procedures by limiting amount of tooth preparation.

A cast post and core should fit passively in the canal and allow for sufficient space for the luting agent used. Several tryins are necessary to completely seat the castings, passively. In photoelastic studies active post engagement have led to high stresses, which may increase risk of root fracture. Therefore it is necessary to fabricate slightly undersized posts to allow for passive fit and cement placement[19] The study was carried out to obtain undersized cast post and cores to prevent root fractures. Shrinkage of the mould cavity was the desired effect during casting procedures with cast post and cores. A consistently undersized post would seat passively in the canal & allow for enough luting agent. The study was carried out to evaluate the influence of ceramic ring liner and lower casting ring temperature on the dimension of cast posts.

In this study a phosphate-bonded investment (Supervest) was used to prepare the mould cavity. It showed setting expansion of 1% and a thermal expansion of 1.3% (Manufacturer's data). The alloy used for preparation of castings was nickel chromium allow (Sankin) with melting 1150°C and showing a casting shrinkage of 2%. For two groups in the study (1 & 3) a ceramic liner which was prewetted was used. The ceramic liners are made of fibres of an alumino silicate glass derived from kaolin by means of standard paper making techniques (Barnard 1981). The major components in glass are alumina (47-65 wt%) and silica (38-50 wt%) so that the material is highly heat resistant, being suitable for service even at 1300°C. Care was taken to locate the patterns centrally in the ring and achieve standardisation in wetting the ring liner. The firing cycles used in group 1 & 3 are recommended by the manufacturer for the given phosphate bonded investment to achieve the total thermal expansion of 2.3%.

The dimensional changes occurring in the castings were measured at 2 different notches along the length of the post with a Nikon's Measuroscope (2 co-ordinate measuring machine]

The results of the study show that there is a significant dimensional change between resin pattern and cast posts for all 4 groups at both the notches. (graphs 2 & 3). The mean values for groups (1) and (3) (groups with liner present) at notches A & B show that the castings are consistently larger while those in groups (2) and (4) (groups without liner) show that castings are smaller in width. These results are in accordance to the previous studies.[10,12] An unlined metal ring does not allow investment setting expansion, but rather restricts or redirects the expansion inwards with the resultant shrinkage of the mould cavity. These findings are in agreement with the previous studies[10,12] which demonstrate that unlined rings produce undersized castings. In the same study by Fusayama[11] it was reported that larger the ring greater the casting shrinkage. This observation suggests that a decreasing percentage expansion occurred as the ring diameter Increased. Davis[15] m his study on the effect of ring liner on the setting expansion, confirmed that metal ring to ring liner volume ratio is one of the key determinants of the magnitude of radial setting expansion. In particular, mean radial setting expansion in lined rings is inversely related to the ring volume to ring liner ratio.

Shell,[11] Shell and Hollenback[12] and Palmer et al[13] observed complete inhibition in the investment setting expansion of unlined rings. Nasu & Noguchi concluded that the cushioning ability of lining materials was not sufficient, the mold shrank. They concluded that the shrinkage of a smaller cavity was greater than a larger cavity which suggest that larger thickness of investment was responsible for greater shrinkage. Shell & Hollenback[12] modified a vitreous silica cylinder expansion first described by Hollenback and Rhoads so that both lateral and longitudinal setting and thermal expansions of investments could be determined. When no liner was used the lateral setting expansion was 0.03% and longitudinal expansion was 0.08%. This was 7 times less from a full liner. When casting ring was not lined the total investment expansion was much less in absolute values and at high temperatures and the longitudinal expansion was greater than transverse expansion because of restrictive effect of casting ring.

The liner used in groups (1) & (3) was prewetted ceramic liner. Steinbock & Azgar[14] and Warfield et al reported that ceramic liners gave a casting inaccuracy not significantly different from that of asbestos, while Gil et al reported that cellulose and ceramic liners gave a satisfactory fit. Thus, the relative accuracy in lined rings would depend largely on mold expansion occurring diametrically in mould core. Hence the ring liners allowed contribution from both setting and thermal expansion. The actual mould expansion depends on the investment, modified by the presence of ring, the ring liner and the resin pattern.

Since the liners in group 1 & 3 were wet, the release of water to the investment could have caused an increase in the setting expansion possibly leading to an increased mold cavity expansion when compared to unlined rings.

The results of the study show that the difference between the mean of dimensional changes in width between groups 1 & 3 is not significant, while that of 2 & 4 is significant. This can be explained with the phenomenon that with larger restrictive stresses a lower expansion is obtained and increased contraction after inversion occurs.[19]

The comparison between mean of dimensions of cast posts shows that groups (2) & (4) produced smaller castings. Also, comparison between the groups indicates that castings in group (4) were significantly smaller than other groups. This could be explained on the difference in the pattern of the thermal expansion between metal ring and investment during heating. The expansion of the metal casting ring follows a linear pattern, whereas the investment has double sigmoid pattern.[8] Therefore at selected temperature - 700°C, this different pattern of expansion could have caused a potential restriction or redirection of the investment thermal expansion. This phenomenon has been observed on a previous investigation, in which a restriction of diametrical expansion was noted in temperature range 250°C to 550°C. Although the compressibility of the ring liner could have accommodated for this differential expansion in group (1) & (3) a restriction or reduction of diametrical thermal expansion could have occurred in group 4 which accounted for the dimensional shrinkage in this group. Thus the pattern of different thermal expansion of metal ring and the investment affect the dimensions of cast posts.

The dimensions of a cast post and core are determined by the dimensions of the investment mould space into which the molten alloy is cast. The dimensions of the mould space are determined in part by the setting expansion of the investment material. Mould spaces are often oriented vertically in the casting ring. Setting expansion of phosphate bonded investment is sensitive to restrictive stress and thus more expansion occurs vertically than horizontally in a casting ring. The vertical and horizontal setting expansion was measured for phsophate-bonded investment in relation to horizontal restrictive stress by Stevans and Junner. A correlation between horizontal and vertical expansion showed that anisotropic expansion occurred in rigid rings while isotropic setting expansion was produced by the use of flexible rubber ring offering little or no restriction to setting expansion. Restrictive stress produced by the rigid metal ring produces greater axial expansion and decrease in dimetrical expansion. This phenomenon known as anisotropic setting expansion causes a significant distortion in the mould cavity if the pattern is located horizontally. The results of the study agree with the above findings. There is a significant increase in length between notches A and B for all 4 groups. A negative correlation is found in groups (2) and (4) [Table 5] between width and length. It is observed that though the width of the posts has decreased, the length has increased. However, since the castings are oriented parallel to the long axis of the ring, the distortion of the mould space produced by anisotropic expansion causes longer posts which could be adjusted easily.

SUMMARY AND CONCLUSION

Prosthodontic treatment of an endodontically treated tooth poses a challenge to the practitioner. Endodontic therapy has provided a solution to retain mutilated teeth. Coronoradicular reconstruction in the form of cast post and core is used as a method to provide retention and resistance form to the restoration. In restoring an endodontically treated tooth a critical step is dowel placement. Vertical and horizontal root fractures can occur as a result of excessive removal of tooth structure during root canal treatment, dowel placement or inceasing the width of the dowel. A cast post and core should fit passively in the canal. Even a minimally oversized post can lead to transfer of stresses to the canal walls and increase the risk of root fracture. Therefore it is necessary to ensure that there is passive fit of the post and core. Shrinkage of the mould cavity is desired during the casting process to allow a passive fit.

This study evaluated the effect of a ceramic ring liner and a lower casting temperature of the metal ring on the dimensions of cast posts. The following conclusions can be drawn from the study.

1. Investing in lined metal ring using a casting ring temperature of 900°C resulted in oversized posts (group 1, A: 1.242 and B: 1.243)
2. Investing in unlined metal rings using a casting ring temperature of 900°C resulted in undersized posts (group 2: A: 1.156 and B: 1.165).
3. Investing in lined metal rings and using a casting ring temperature of 700°C resulted in oversized posts (group 3: A: 1.230, B: 1.233).
4. Investing in unlined metal rings and using a casting ring temperature of 700°C resulted in undersized posts (group 4: A: 1.101, B: 1.106).
5. For both temperatures absence of ring liner produced undersized posts.
6. The combined effect of decreasing the casting ring temperature and absence of ring liner significantly decreased the dimensions of cast posts.
7. Absence of ring liner resulted in a relatively more increase in length as compared to presence of ring liner.

Table 5: Comparison between measurements of lengths of resin patterns and cast posts in each of four groups

Groups	Mean	SD	Unpaired *t*-test*	*P*-value	Significant
Pretreatment	5.077	0.007	4.184	<0.05	S
Group 1–900°C with liner	5.114	0.027			
Pretreatment	5.077	0.007	2.895	<0.05	S
Group 2–900°C without liner	5.117	0.043			
Pretreatment	5.077	0.007	3.395	<0.05	S
Group 3–700°C with liner	5.117	0.036			
Pretreatment	5.077	0.007	3.032	<005	S
Group 3–700°C without liner	5.113	0.037			

This study found that decreasing the casting ring temperature from 900°C to 700°C along with the absence of ring liner, produced undersized cast posts. Absence of the ring liner itself can be used as a measure to produce undersized castings, keeping the temperature as recommended by the manufacturer. The dimensions of the cast post and core are determined by the dimensions of the investment mould space into which molten alloy is cast. The dimensions of the investment mould space are determined by controlling the expansion of the investment material by altering casting ring temperature and presence of ring liner. The preparation of root canal to receive the post, the cement thickness, the amount of seating force and the masticatory force all play a critical role in the final restoration. Hence, though the results can be extrapolated to clinical situation long term *in vivo* studies and objective clinical evaluations are necessary to predict the *in vivo* behaviour of cast posts.

REFERENCES

1. Healey HJ. Coronal restorations of the treated pulpless teeth. DCNA: 1957. p. 885-96.
2. Rosen H. Operative procedures on mutilated endodontically treated teeth. JPD 1961;11:973-86.
3. Barban DJ. The restoration of pulpless teeth. DCNA 1967;11:633-53.
4. Sokol DJ Effective use of post and core concepts. JPD 1984;52:231-4.
5. Standlee JP, Caputo AA, Trabert KG. The retentive and stress distributing properties of threaded endodontic posts. JPD 1992;68:436-42
6. Cooney JP, Caputo AA, Trabert KC. Retention and stress distribution of tapered end endodontic posts. JPD 1986;53:540-6.
7. Standfee IP, Caputo AA, Collard EW, Pollack MH. Analysis of stress distribution by endodontic posts. Oral Surg Oral Med Oral Pathol 1972;33:952-60.
8. Rice WS. Dimensional dental castings. JADA 1931;18:1280-7.
9. Fusayama T, Sakurai S, Suzuki E. Expansion of investment in casting rings. Bull Tokyo Med Dent Univ 1957;14:327-41.
10. Morey EF, Earnshaw R. The fit of gold alloy full crown castings made with prewetted casting ring liners. JDR 1992;71:1858-64.
11. Shell JS. Gold castings with special reference to inlays. JADA 1923;10:187-200.
12. Shell JS, Hollenback GM. Setting, thermal expansion in longitudinal and transverse direction. J Calif Dent Ass 1965;41:511-4.
13. Palmer DW, Rodyhouse RH, Skinner EW. Asbestos liner and casting accuracy. Dent Pog 1961;1:156-63.
14. Steinbock DJ, Azgar K. A possible substitute for asbestos as casting ring lining material.JDR 1978;57:255-724.
15. Davis DR. A review of experimental evidence of carcinogeneicity of man made vitreous fiber. Scand J Work Environ Health 1987;12:12-7.
16. Mattison GD. Photoelastic stress analysis of cast gold endodontic posts. JPD 1982;48:407-11.
17. Mattison GD. Von Fraunhouf Angulation loading effects on cast gold endodontic posts, a photoelasticanalysis. JPD 1983;49:639.
18. Chan RW, Byzant RW. Post core foundations of endodontically treated teeth. JPD 48;401-1982.
19. Castillo DR, Carlos E, Gerald G, Ross H, Moss MC. Effect of ring liner and casting ring temperature on dimensions of cast posts. JPD 2000;84:32-7.