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Laboratory Research

Predictable Casting for Dimensional Shrinkage of Fast-cast Post-and-cores

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Clinical Relevance

A cast post-and-core needs to be slightly smaller than the space created for it. This paper looks at three methods to cast post-and-cores and evaluates the predictability of dimensional shrinkage for the three methods. The use of a phosphate investment with an accelerated technique can produce shrinkage with consistency in dimensional stability.

SUMMARY

Statement of problem: Prior investigations into dimensional shrinkage of fast-cast post-and-cores resulted in variable dimensions. There is a need for consistent shrinkage of cast post-and-cores to reduce or eliminate lateral stresses on the remaining tooth structure.

Purpose: The purpose of this research was to find a method of casting post-and-cores that would result in consistent shrinkage.

Material and Methods: A total of 45 methyl methacrylate post-and-core patterns, 10 mm long, were fabricated from a standardized steel block. Three methods were used to cast the post-and-core. Investment materials used were Fast Fire 15 (Whip Mix Corp, Louisville, KY, USA) and Beauty Cast gypsum (Whip Mix Corp). Three groups of sample post and core patterns were cast, varying the investment material used and the burnout time.

Results: Results show a statistical significance between the investment materials ($p<0.05$). The accelerated technique produced the most consistent results, and all samples had shrinkage of the casting.

Conclusions: The use of a phosphate investment with an accelerated technique can produce consistent and predictable shrinkage of cast post-and-cores.

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INTRODUCTION

The development of the casting process in dentistry undoubtedly represents the greatest single forward step in the science and art of the profession that has been made. The casting process, which Dr. Taggart gave the profession in November 1907, is almost identical to the one used today. Although others conceived the idea of the cast restoration prior to Taggart, they did nothing to bring the technique into a state of perfection whereby it could be used by the profession.[1] The ability to cast metals into an investment mold with a minimum for bench set time and oven time will allow the technician or dentist to work faster and produce more. This is especially important in the casting of custom post-and-cores. Post-and-cores are fabricated to provide retention and resistance for crowns and fixed partial dentures.[2] Rosenstiel et al[2] and Baba[3] recommended the use of a cast post-and-core for anterior teeth with flared or elliptical canals. The conventional method of casting a post-and-core is time consuming and requires the patient to make two appointments. This process involves a minimum of 2¼ hours of laboratory time: sprueing and investing, 10 to 15 minutes; investment setting, 45 to 60 minutes; and staged burnout and casting, a minimum of 60 to 75 minutes.[4] The process can be frustrating and time consuming for the dentist as well as the patient. The dentist must reschedule the patient and fabricate a provisional restoration. Rescheduling the patient is expensive and inconvenient.

In 1991, W.V. Campagni and M. Majchrowicz[5] were the first to introduce an accelerated technique for custom post and cores. The accelerated casting procedure may reduce casting time to 30 to 40 minutes. Initially suggested as a way to make cast post-and-core restorations a one-visit procedure, the procedure has been found to produce castings with accuracy and surface roughness similar to traditional methods.[6] The accelerated technique of pattern elimination has received increased attention as a method of improving productivity. Hansen et al[6] showed the quality of the fast-cast castings to be identical to that of a slow, conventional technique. Although quality is the same, all techniques showed shrinkage or expansion. There is a need for a technique that would give predictable shrinkage for all castings.[6] The cast post-and-core has been recommended, as opposed to a prefabricated post, because it requires less tooth instrumentation in correlation with a lesser degree of tooth perforation.[7] The cast post-and-core restoration also has the ability to resist rotational forces, which is not possible with a prefabricated post system.[8,9] An undersized cast post may also limit the stress placed on the radicular tooth structure, possibly decreasing the likelihood of root fracture.[4,10] Figure 1 shows the effect of a casting that may be too large for the prepared space. A post should rest on a flat area 90° from the post space, with a small amount of space between the post and the tooth root for the luting agent.[2,3]

The fast-cast technique shortens certain time intervals of the conventional method. The first reduction is the mold's bench-setting time. As soon as the mold for the fast-cast technique has reached adequate wet strength, the mold is placed into a preheated furnace. The second reduction is the pattern's elimination time in the furnace. The elimination-time reduction is a combination of placing the mold in a preheated furnace and limiting its time at maximum temperature to 15 minutes.[5,10,11]

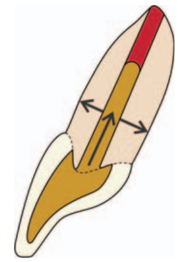

Figure 1. *If the post-and-core is larger than the corresponding post space, lateral pressure will be placed on the root of the tooth and can possibly lead to fracture of the remaining tooth.*

A cast post-and-core should fit somewhat loosely in the canal because a tight fit may promote root fracture. The casting should be slightly undersized, which can be accomplished by restricting expansion of the investment (ie, by omitting the usual ring liner) or changing the direction of the expansion.[10,12,13] Post-and-core restorations must be carefully placed into the tooth during trial insertion because resistance to full seating of the casting can cause tooth fracture as the casting binds and attempts to expand the tooth (Figure 1). The post-and-core should seat passively with little discernible movement or rotation. If significant movement occurs, a new post-and-core must be made that has better adaptation.[14] An undersized cast post is easier to fit and cement in the prepared root canal, which reduces chair time.[10]

In order to consistently shrink post-and-cores, an investment material and technique that is reproducible and capable of tolerating the accelerated techniques of fast casting must be used. It is essential to avoid using a ring liner when investing resin patterns because the liner compensates for investment expansion.[4] By using an unlined stainless steel ring, the investment cannot expand outward and is forced toward the center of the mold, resulting in a smaller mold cavity (Figure 2). Gypsum-bonded investment is capable of expansion inward, resulting in post shrinkage. The problem with gypsum investment is that it is not capable of tolerating the reduced bench set, the preheated oven temperature of 1300°F, and the accelerated burnout in the oven.[4] A phosphate-bonded investment must be used for this accelerated technique. Phosphate-bonded investment materials offer certain advantages over gypsum-bonded investments. They are more stable at high temperatures, they expand rapidly at the temperatures used for casting alloys, and their size can be conveniently controlled. The increased expansion that they exhibit results from a combination of the following factors:

1. The high heat from the oven quickly vaporizes the resin pattern, allowing the expansion of the phosphate-bonded investment to compress the void where the pattern had been.[4]
2. The increased strength of the material at high temperatures restricts shrinkage of the alloy as it cools.[4]
3. The powder mixed with colloidal silica reduces the surface roughness of the castings and also increases expansion.[4]

Expansion can be conveniently controlled by slightly diluting the colloidal silica with distilled water due to the higher casting temperature compared with gypsum-bonded investment.[12,13] The principal difference between gypsum-bonded and phosphate-bonded investments is the composition of the binder and the relatively high concentration of silica refractory material in the latter. The binder consists of magnesium oxide and an ammonium phosphate compound. Contrary to gypsum-bonded products, this material is stable at burnout temperatures above 650°C (1200°F), which allows for additional thermal expansion. Most phosphate-bonded investments are mixed with a specially prepared suspension of colloidal silica in water. Increasing the proportion of special liquid (colloidal silica) also increases expansion.[14,15]

The purpose of this study was to develop an accelerated casting technique that consistently produces post shrinkage. There is shrinkage with gypsum-bonded investments, but they cannot tolerate the stress of fast casting.[5] The focus was on Fast Fire 15 (Whip Mix Corp, Louisville, Ky), a phosphate-bonded investment.

MATERIALS AND METHODS

A total of 45 Duralay resin (methyl methacrylate, Reliance Mfg Co, Alsip, IL, USA) post patterns were used in this study. These patterns were fabricated by inserting the resin into a stainless steel block that contained a 2.5 × 2.0-mm tapered hole (Figure 3). The taper on the steel die was fabricated to allow the resin pattern to be made, cast, and measured for expansion or shrinkage of the casting. A plastic sprue (Whip Mix Corp) was placed into the resin and allowed to set for five minutes. The resin post was removed from the block and was placed in a crucible former (Whip Mix Corp); the length of each resin post was measured for consistency. Each pattern was inspected for defects and discarded if any were found.

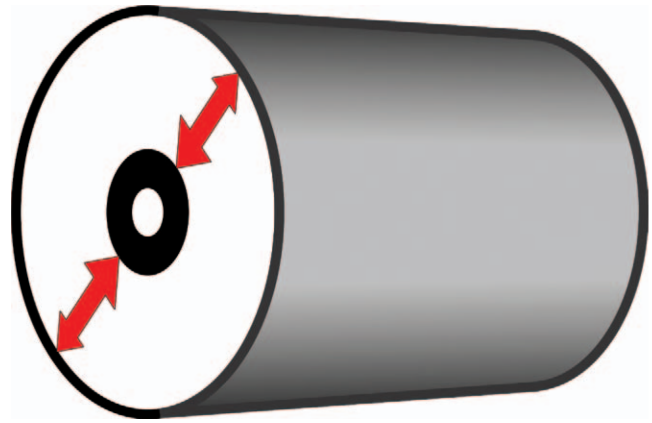

Figure 2. *Expansion of the investment material will press against the walls of the casting ring. Because the casting ring becomes a restricting force to prevent outward expansion, the investment will actually compress the void left from the resin pattern. The result will be a slightly smaller casting than the original pattern.*

The resin posts were divided into three groups of 15. Each investment type has variable bench set and burnout times (Table 1). The Beauty Cast (Whip Mix Corp) gypsum investment (group 1) and the Fast Fire 15 (Whip Mix Corp) (group 2) were prepared according to the manufacturer's instructions. The Fast Fire 15-A (group 3) was the accelerated investment. For group 1, each pattern was lightly sprayed with a surfactant agent (Smoothedex debubbilizer, Whip Mix Corp). Each resin post was invested with a gypsum-bonded investment (Beauty-Cast, Whip Mix Corp) using the manufacturer's recommendation. According to Shillingburg,[13] adding 1.0 to 2.0 cm^3 of extra water to 50 g of investment and not using a ring liner in the casting ring will result in a slightly smaller dowel core that should have less tendency to bind in the canal. Therefore, to ensure shrinkage, and to follow Shillingburg's protocol, 1.0 cm^3 of extra water was added to the manufacturer's recommendation. Following the manufacturer's recommendations, the distilled water was measured at 72°F, the Beauty Cast (Whip Mix Corp) was hand mixed for 15 seconds, vacuum mixed on slow speed for 40 seconds, vibrated into the stainless steel casting ring measuring 1¼ inches

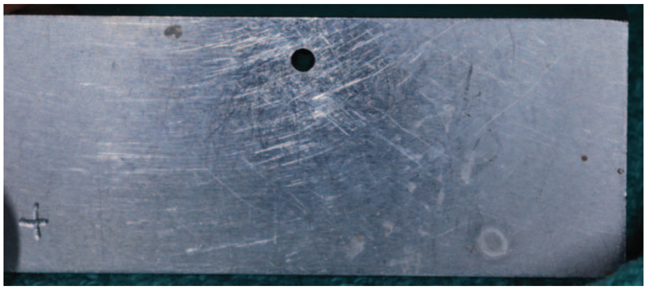

Figure 3. *The stainless steel block with the tapered space to form the resin pattern to be cast.*

diameter × 1⅞ inches high (Whip Mix Corp), and bench set for 30 minutes. The casting ring was placed in the Accu-therm oven (Jelenko, San Diego, CA, USA) at room temperature and allowed to slowly heat from room temperature (approximately 75°F) to 1200°F, at which point the investment was allowed to heat soak for one hour.

For group 2, the phosphate-bonded investment (Fast Fire 15, Whip Mix Corp) was prepared using the manufacturer's recommendation. For group 3, the accelerated casting technique, a phosphate-bonded investment (Fast Fire 15-A, Whip Mix Corp) was used. A 20:80 distilled water-special liquid (colloidal silica, Whip Mix Corp) solution was incorporated with the investment powder. Shillingburg stated that a high silica and low water mixture will result in more expansion of the investment.[13] The total liquid volume was reduced by 2 mL to give a more viscous mix. Some latitude in expansion can be gained by altering certain of the variables found in the investment procedure. Decreasing the powder-liquid ratio reduces the setting expansion slightly, and vice versa. That is, if 50 g of investment is used with 17 mL of water to produce an average degree of setting expansion, the use of 18 mL of water would decrease expansion and 16 mL would increase expansion.[15] The Whip Mix Corp also recommends using more special liquid and less water to achieve maximal expansion.[14] The investment was hand mixed for 125 seconds, vacuum mixed on slow speed for 15 seconds, bench set for 15 minutes, and put in a 1300°F preheated oven for 15 minutes, following the manufacturer's recommendations.

A single operator performed the investing and casting procedures. All castings were performed with a natural gas torch (National Blowpipes, Keystone Industries, Cherry Hill, NJ, USA) using 4 dwt of new Ney-Oro B-20 type III gold (Dentsply, York, PA, USA). The arm of the casting machine (Kerr Centrifico Casting Machine, Orange, CA) was totally unwound prior to each casting and was then rotated clockwise until the first stiff resistance was met; from that point, three full turns were applied. Once the gold was melted, it was dusted with Ney casting flux (Degussa-Ney Dental, Yacaipa, CA, USA) to dissolve any oxides formed. The gold was then centrifuged into the mold upon release of the casting machine arm. The casting ring was quenched in cold water before devesting. The castings were soaked in Stripping Acid (American Dental Supply Inc, Allentown, PA, USA) and placed in the ultrasonic for five minutes to remove any residual investment material. The posts were steam cleaned and then inspected under a 6×-magnification microscope (Swift Instruments, Schertz, TX, USA) (Figure 4). All nodules were removed from the post using a ¾-inch medium sandpaper disk (EC Moore Company, Buffalo Grove, IL, USA). Small nodules on the cast post can cause wedging stresses that precipitate root fracture. A single air bubble entrapped when the pattern is invested can produce a positive nodule on the metal post.[13]

The measurement of the cast post was performed by placing the casting back into the steel block, giving a half-twist clockwise and applying a 70-g weight to completely seat the post (Figure 5). Post-and-core restorations must be carefully placed into the tooth during the trial insertion. No attempt should be made to force the casting into position in the tooth. A steady but modest force should be applied with the fingers or a hand instrument until complete seating is achieved. It was evident that shrinkage had occurred if the post was able to pass through the tapered hole in the steel block. If the casting was unable to fit back into the block and have the end of the post reach the bottom of the steel block, the casting had expanded. A traveling 32×-magnification microscope (Gaertner Scientific Cor-

Table 1: *Investing and Casting Variables*

Investment	Investment Properties	Casting	Burnout (°F)	Bench Set	Burnout
Beauty Cast	Gypsum bonded	Manufacturer recommended	75–1200	30 min	60 min
Fast Fire 15	Phosphate bonded	Manufacturer recommended	1300	15 min	30 min
Fast Fire 15-A	Phosphate bonded	Accelerated	1300	15 min	15 min

Figure 4. *The casting made from type III gold. The casting is sprued, then cast.*

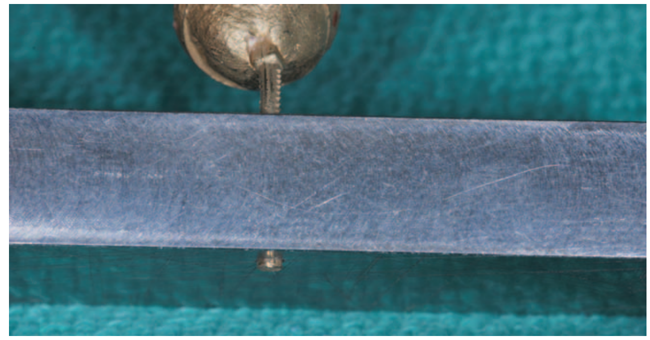

Figure 5. *The casting tried back in the steel block after examination to ensure no nodules are present on the casting. If the casting is smaller, it will pass through the channel, and the tip will protrude out the inferior border of the steel block. The length of the post is measured from the tip of the post to the border of the steel block.*

poration, Chicago, IL, USA) was used to measure (in millimeters) the protrusion of the post from the tapered hole. Measurements were made from the apex of the post to the flat bottom of the steel block. For the posts that expanded, an impression was taken of the space left in the tapered hole using polyvinylsiloxane (President, Coltene Whaledent, Cuyahoga Falls, OH, USA); the impression was measured with the traveling microscope to determine how much it expanded. Measurements were made from the apex of the polyvinylsiloxane impression material to the image of the bottom of the steel block.

RESULTS

Means and standard deviations were calculated for each group. This study was a one-factor, completely randomized design. A one-factor analysis of variance with Fisher least significant difference post hoc test was used to determine which pairwise contrasts were significant (Table 2).

The Beauty Cast investment (group 1) resulted in shrinkage of all 15 castings, with the largest mean shrinkage of –0.6914 mm. The Fast Fire 15 (group 2) resulted in only eight castings that shrank, with a mean of –0.0281 mm; four that expanded; and three that fit the steel die perfectly, meaning there was neither shrinkage nor expansion. The Fast Fire 15-A (group 3) resulted in shrinkage of all 15 castings, with a mean shrinkage of –0.3348 mm and a standard deviation of 0.1782. Refer to Table 3 for individual casting results. The results show a statistical significance between the different investments when testing for dimensional stability ($p<0.05$). Even though the Beauty Cast produced the most shrinkage, it also had the most variance in its results, with a standard deviation of 0.3946. The investment with the least amount of variance was the Fast Fire 15-A, with a standard deviation of 0.1782. This shows that the accelerated technique produced much more consistent results than the other investments.

In order to examine the reliability of the measurements, the author blindly remeasured 10 castings using the same microscope. A Pearson correlation coefficient was computed between replicated measurements. A correlation coefficient of $r = 0.999$ was obtained. This coefficient confirmed that the measurements were accurate and reproducible.

DISCUSSION

Each investment considered for the accelerated technique requires individual evaluation. The use of a standardized accelerated investment procedure for all types of investments is not advisable.[5]

The results of this study show that the accelerated casting technique using Fast Fire 15 produced post shrinkage with no significant standard deviation. The Beauty Cast has been shown[6] to produce post shrinkage and did so in this study as well, but with a significant standard deviation. It is important to point out that the Beauty Cast investment took a considerable amount of time to produce a cast post: a 30-minute bench set, slow oven heating from 75°-1200°F, a one-hour heat soak, and, to produce

Table 2: *Mean and SD for Each Group (mm)*

Investment	Mean	Standard Deviation
Beauty Cast	–0.6914(a)	0.3946
Fast Fire 15	–0.0281(b)	0.2818
Fast Fire 15-A	–0.3348(c)	0.1782

Table 3: *Dimensional Stability—Individual Results*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
BC	−1.729	−0.423	−0.425	−0.786	1.44	−0.442	−0.344	−0.79	−0.767	−0.663	−0.361	−0.572	−0.575	−0.515	−0.539
FF	−1.66	−0.192	0.628	0	−0.062	−0.28	0	−0.12	−0.315	0.086	−0.334	−0.371	0.361	0	−0.286
FF-A	−0.66	−0.16	−0.372	−0.319	−0.374	−0.172	−0.241	−0.428	−0.593	−0.637	−0.34	−0.261	−0.174	−0.158	−0.133

Abbreviations: BC, Beauty Cast; FF, Fast Fire 15; FF-A, Fast Fire 15-A.

another casting, the oven must be cooled back down to room temperature. This entire process took 5 hours 25 minutes to complete. In comparison, a cast post was produced in 30-40 minutes using the accelerated technique. It is important to note that both Fast Fire 15 investment groups consistently produced smoother castings, which decreased the time required to sand the nodules from the cast. Several of these did not require sanding at all. This is another positive factor that may reduce chair time.

It is necessary to use a casting ring with no liner. The absence of the ring liner and the direct contact of the investment material with the metal casting ring constitute a physical restraint to the investment's expansion.[2,17] It is important to use a rigid casting ring to ensure that it can contain the thermal expansion of the investment and redirect the expansion inward to give a smaller mold cavity, resulting in smaller castings (Figure 2). Stainless steel, although relatively expensive, produced the hardest, strongest, and most acceptable casting ring.[16] Investment expansion directed inward by the rigid casting ring caused a reduction in the volume of the mold cavity.[16] During the thermal expansion of the investment, the mold is empty after the elimination of the resin pattern. The outside walls of the mold are pressed inward by the expansion of the investment, which is supported by the ring.[17] By using a 20:80 distilled water-special liquid solution and decreasing the total liquid mixture by 2 mL, a thicker and more expansive investment was produced, which aided in the dimensional shrinkage results.

CONCLUSIONS

A slightly undersized post can be produced using a conventional gypsum investment technique, but this procedure would require more than one office visit. The use of a phosphate investment with an accelerated technique can produce shrinkage with more consistency in dimensional stability. By choosing a casting technique that can achieve the same results in one day instead of a two-office visit procedure will ultimately save the dentist chair time and, therefore, allow for more productivity.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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