Dental Molding Compounds and Casts: Use in Non-Laboratory Environments

Rebecca K. Scopa Kelso[1*], Brannon I. Hulsey[2], and Kathryn R.D. Driscoll[3,4]

[1]Department of Biomedical Sciences, West Virginia School of Osteopathic Medicine, Lewisburg, WV
[2]Department of Anthropology, University of Tennessee, Knoxville, TN
[3]Heartland Community College, Normal, IL
[4]Illinois State University, Normal, IL

Keywords: dental casts, dental morphometrics, molding compound

ABSTRACT Dental casts are invaluable research tools. There are a variety of molding compounds available, all having temperature, humidity, and timing guidelines to ensure a precise replica of dentition. However, not all field research conditions allow for adherence to environmental guidelines requiring longer wait times prior to pouring epoxy for casting. This study tests a common molding compound in non-controlled environments and over varying time intervals, testing the integrity of the dental molds in producing precise replicas of original teeth. Five hundred and eight molds were created under three varying environments: room temperature, hot/humid, and cold/dry. Molds were removed from these environments in two-week intervals over twelve weeks. The resulting casts were measured to determine timing limitations for producing accurate dental casts under varying environments. Molds stored at room temperature retained their shape and size for the complete twelve weeks. Molds kept in a hot and humid environment, however, only maintained their shape and size up to four weeks, whereas molds in a cold and dry environment showed significant changes by the end of the second week. These findings provide additional tools for researchers working in a variety of field conditions allowing casts to be taken of specimens that cannot be transported off site.

Adequately documenting archaeological and paleontological dental remains in the field can be a problem when the dentition cannot be removed from their archaeological site, museum collection, or country of origin. Macroscopic analysis, such as enamel hypoplasia and microwear studies, rely on visual inspection of the dentition. Instead of relying solely on notes, sketches, and photographs, it is ideal to make replicas of the teeth that could then be taken home for further analysis such as studies on microwear and dental enamel hypoplasia (Egocheaga, 2004; Mihlbachle, Foy, & Beatty, 2018; Stynder et al., 2018; Ungar, Livengood, & Crittenden., 2019; Ungar & M'Kiera, 2013; Ungar & Williamson, 2000). The process of making an accurate replica of a tooth requires using a molding compound to create a mold and then the use of either an epoxy or stone casting material filling the mold, to produces an accurate cast. In order to produce casts with exactly the same dimensions as the original tooth, the guidelines provided with the molding and casting compounds should be followed precisely. While many field research opportunities require one to be away from climate-controlled workspaces for weeks or months at a time, most molding compounds require casts to be made from their products within one week of forming the mold. Often times archaeological or paleontological dental remains are not allowed to leave their country of origin, compelling an alternate method for research to continue after returning to one's home location. Field research can last from only a few days to a few months, which could make following the material guidelines problematic in many field research settings. Additionally, it is recommended that the molding compound and subsequently created molds be kept at room temperature (~72˚F) (Coltène Whaledent, 2018), which is not always attainable for extended periods in field

*Correspondence to:
Rebecca Scopa Kelso
Department of Biomedical Sciences
West Virginia School of Osteopathic Medicine
rscopkelso@osteo.wvsom.edu

research conditions.

In many cases, making dental molds to transport back to one's home research location is more advantageous than making the molds and casts in the field for several reasons. If the field research location is in a remote area flying with casting material can be difficult. The excessive physical weight of dental stone before and after it has been cast can be a limiting factor for air travel and shipping, as well as its relative fragile nature once cast. Additionally, 2-part epoxy components contain both a Class 8 Corrosive Liquid and a Class 9 Hazardous material. Flying with these components is against the Federal Aviation Administration regulations and shipping can be problematic, requiring special labeling and specific delivery locations. Therefore, traveling with the lighter inert components of the molding compounds would be advantageous.

However, is it still a viable option to use these molding compounds when research conditions are less than ideal? What happens when field sites are in more extreme environmental conditions and research facilities have little or no environmental controls, requiring molding compounds and molds to be used and stored outside the material temperature and humidity guidelines? To determine the range of conditions under which the integrity of the molds can be maintained, we tested a commonly used molding compound, President Putty Soft (Grine & Kay, 1987; Mahoney, 2006; Nystrom, Phillips-Conroy, & Jolly, 2004; Teaford & Oyen, 1989; Ungar, 1996), in a variety of environments for varying lengths of time. Molds were made and placed in three environments chosen to imitate potential field conditions: room temperature, hot /humid, and cold/dry. Molds were removed for epoxy casting in two-week intervals to determine if and when the molds become compromised and cast dimensions deemed unreliable.

Materials and Methods
For this study, the commonly used molding compound Presidential Putty Soft (Coltène-Whaledent, 2018) (Figure 1) was tested for its ability to maintain integrity over time in differing environments. Disposable paraffin embedding molds were used in two sizes to contain the molding material throughout the project, rectangular 22mm x 40mm x 20mm deep held two tooth impressions and 22mm x 22mm square x 20mm deep held one tooth impression (Polysciences, 2019). Twelve maxillary premolars were used to make 49 impressions each for a total of 588 tooth molds within a two-hour

time frame (Figure 2). The molds were then equally divided into groups of 196 and placed in three separate environments: room temperature, hot/humid and cold/dry. After removal from the test environments Epotek 301 (Epoxy Technologies, 2019) was poured into each mold to form a cast of the individual tooth. Epoxy was chosen over a dental stone casting material like gypsum due to its durability and common use in the field (Egocheaga, 2004;

Figure 1. Molding compound

Figure 2. Dental mold

Mihlbachle, Foy, & Beatty, 2018; Stynder et al. 2018; Ungar Livengood, & Crittenden, 2019; Ungar & M'Kiera, 2013; Ungar & Williamson, 2000).

Three artificial environments were constructed to simulate nonenvironmentally controlled environmental field conditions. The first set of 196 molds was placed in a typical indoor climate controlled environment with the environmental controls set to 72° Fahrenheit and a relative humidity (RH) of approximately 50% (ASHRAE, 2017). The second environment was designed to simulate

field conditions in places like the highlands of Peru, the Alps, and Siberia, so a set of 196 molds was placed in a refrigerator with a drying agent, a 10oz container of calcium chlorite moisture absorber, mimicking the effects of a cold and dry environment; the average temperature was 32°F with a variance with a RH of approximately 33% (Figure 3). The final set of 196 molds was placed in an insulated aquarium with a heat source, a reptile under tank heater, set to 95°F and kept the bottom of the tank covered with water between a ¼ of an inch to 1 inch of water to attain an average temperature of 95°F and an approximate RH of 99% (Figure 4). This hot and humid test environment was designed to replicate field conditions found in Central America, Southeast Asia, and parts of Oceania. Air temperature and relative humidity were monitored in each environment by placing HOBO automatic data logger sensors placed directly beside the molds throughout the entirety of the study. Each of the three sensors was set to record the air

Figure 4. Hot humid environment

Figure 3. Cold dry environment

temperature and relative humidity of the study environment every 6 hours to ensure that conditions were maintained.

Table 1 provides the summary data for the three test environments. The HOBOs showed that the temperature in the in "Room Temperature" test environment averaged 70.5°F with a maximum temp of 78°F and a minimum of 65.6°F and a relative humidity averaging 43.1% with a maximum of 58.7% and a minimum of 37.1% relative humidity. The HOBO readings from within the "Cold and Dry" environment showed that the average temperature was 32°F with a maximum of 34.9°F and a minimum of 30.1°F. The relative humidity in the "Cold and Dry" test environment averaged 31.1% with a maximum of 45.2% and a minimum of 23.9% relative humidity. The "Hot and Humid" environment's average temperature was 94.2°F with a maximum of 99.1°F and a minimum of 88.3° F. The "Hot and Humid" test environment relative humidity average was 95% with a maximum of 98.6% and a minimum of 87.2% according to the environmental HOBO.

Assuming an average summer field season of three months, twelve weeks was used as our total experimental period. According to the President Putty Soft Instructions for Use (2018) casting mate-

Table 1. Environmental test conditions

Test Environment	Average Temperature (°F)	Temperature Maximum (°F)	Temperature Minimum (°F)	Average % Relative Humidity	% Relative Humidity Maximum	% Relative Humidity Minimum
Room Temp	70.5	78	65.59	31.1	45.2	23.9
Cold/Dry	32	34.9	30.1	43.1	58.7	37.1
Hot/Humid	94.2	99.1	88.3	95.3	98.6	87.2

rial can be poured into the molds as soon as thirty minutes after they are made and should remain dimensionally stable for up to 7 days. Within twelve hours of making the molds, Epo-Tek 301 (Epoxy Technology, Inc., Billerica, MA) epoxy was poured into twenty-eight molds left at room temperature to form the control tooth casts. In two-week increments twenty-eight molds were removed from each of the three test environments. The molds were given twelve hours to return to room temperature before casts were poured using Epo-Tek 301 two-part epoxy. Returning the molds to room temperature was designed to simulate returning to a climate controlled research environment to pour the casting material. The Epo-Tek 301 requires approximately 24 hours to harden at which point the casts were removed from the molds for measuring (Figure 5). Due to stretching and damage sustained while removing the dental casts, none of the removed and casted molds were returned to their test environments. A new set of 28 molds were removed for each subsequent two-week casting.
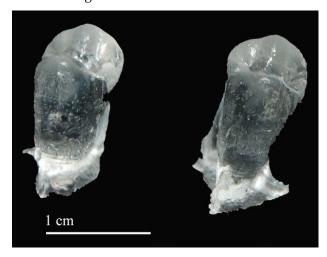

Figure 5. Epoxy casts

Bucco-lingual length, mesio-distal length, and crown height are standard dental measurements used in a variety of research methodologies (Buikstra & Ubelaker, 1994). Due to the relatively small size of teeth, a slight variation in these measurements can create statistical significance and therefore it is imperative that the casted replicas be a completely accurate representation of the original tooth. Therefore, these three measurements were used as markers of any meaningful change in the shape or size of the molds. The bucco-lingual length, mesio-distal length, and crown height of each dental cast was measured using digital calipers consistently by only one of the authors (RSK) to control for inter-observer error. Measurements were repeated for each dental cast in one-week time intervals for a total of three sets of repeat measurements to establish intra-observed reliability with analysis of variance. The observer was blind to the previously recorded measurements and environmental treatment of each casts. Results of repeated measures ANOVA to test for the intra-class correlation coefficients for the three repeated measurements of bucco-lingual length, mesio-distal length, and crown height per tooth were all above 0.90 and therefore considered highly consistent. The three repeated measurements were then averaged together to provide an averaged bucco-lingual length, mesio-distal length, and crown height for each tooth and used to determine if the size of the molds in each environment changed over time. Because the data were not normally distributed, Wilcoxon signed-rank tests were used to test for significant differences between time intervals in each environment.

Results

Table 2 provides summary statistics comparing cast measurements among environmental conditions. Those weeks that differed significantly from the null hypothesis are noted. The number (N) listed in the table refers to only those teeth (with all bucco-lingual diameter, mesio-distal diameter, and crown height measurements) used in that two-week test sample. For example, in "Room Temperature," 28 teeth with three measurements were used providing 84 compared measurements. When successive weeks were significantly smaller, this indicates that the molds and resulting casts were "shrunken" versions of the initial molds and original teeth. Significant increases in measurements in later weeks indicate that the molds and resulting casts were "swollen" versions of the originals.

As shown in the table, the room temperature molds showed no significant changes throughout the entire twelve-week period. This was an expected result; when the molding compound was used as directed, it maintained its integrity. However, this was not the case once the conditions were altered.

The hot/humid molds remained stable until the fourth week, whereupon the cast measurements became significantly larger due to the swelling of the molds than cast made at week 0. This swelling manifested as an increase in the molds in two of the three dimensions, increasing the space left by the dental impression. The statistically significant

change occurred in the fourth week with an increase in the mesio-distal and crown height measurements of the casts. Bucco-lingual changes manifest as a shrinking of the cast and became significantly different from the initial week 0 cast at the sixth-week mark. Even though the Wilcoxon signed-rank tests did not show significant differences between successive weeks compared to the initial week 0 casts until week twelve, additive changes between weeks two and four, as well as weeks 2 and 8 were also significant.

The cold/dry molds showed significant changes by week two in the bucco-lingual direction. All three cast measurements became significantly smaller due to the shrinkage of the casts. This shrinking manifested as a decrease in the overall size of the molds, including the space left by the dental impression. Wilcoxon signed-rank tests between the successive weeks indicated no additional significant differences; however, by week ten, the additive changes between weeks four and ten and weeks four and twelve became significantly different.

Discussion and Conclusions
This study has shown that researchers have adequate time to produce dental molds over the course of a field season and return home to pour the epoxy for casts, producing reliable tooth replicas, if the molds can be kept in an environmentally controlled setting (~72°F and 50% RH). However, molds kept in a relatively cold and dry environment (~39°F and 33% RH) have been shown to shrink significantly within a short period of time (< two weeks). Therefore, molding dental remains would not be appropriate for these field conditions, as the casts would not produce reliable measurements. Using this molding product in a hot and humid environment (~95°F and 99% RH) for a short period of time would be feasible, because molds appear to remain stable for four weeks.

Making dental molds to transport back to one's home research location is more advantageous than making the molds and casts in the field for several reasons. If the field research location is in a remote area flying with casting material can be difficult. The excessive physical weight of dental stone before and after it has been cast can be a limiting factor for air travel and shipping, as well as its relative fragile nature once cast. Additionally, 2-part epoxy components contains both a Class 8 Corrosive Liquid and a Class 9 Hazardous material. Flying with these components is not allowed and shipping can be problematic, requiring special labeling and delivery locations. Considering these factors, the ability to travel with only the molding compounds greatly improves the ease and likelihood of future dental analysis from dental casts.

In summary, researchers can reliably utilize President Putty Soft as a tool for recording dental information from teeth even in a variety of environmental conditions up to a certain period of time. This method will prove especially useful

Table 2. Study results timing of cast changes between test environments

Test Environment	Number of Tooth Measurements Used in Comparison	Change (δ) in Cast Measurements From the Control Group (Week 0)	p Value	Overall Resulting Change in Casts
Room Temperature	84	Week 0 vs. Weeks 2-12 = δ	0.576 (average)	No Change
Hot/Humid	82	Week 0 vs. Weeks 2-10 = δ	0.254 (average)	No Change
		Week 0 vs. Week 12 = δ	0.006*	Swelling
		Week 0 vs. Week 4 (crown height) = δ	.026*	Swelling
		Week 0 vs. Week 4 (mesiodistal) = δ	0.05*	Swelling
		Week 0 vs. Week 6 (bucolingual) = δ	.003*	Shrinkage
		Week 2 vs. Week 4 = δ	0.006*	Swelling
		Week 2 vs. Week 8 = δ	0.001*	Swelling
Cold/Dry	79	Week 0 vs. Weeks 2-12 = δ	0.006*(average)	Shrinkage
		Week 4 > Week 12	0.003*	

when specimens cannot be removed from the archaeological site, museum collection, or country of origin for further analysis.

REFERENCES

ASHRAE (2017). *Thermal environmental conditions for human occupancy. ANSI/ASHRAE addendum b to ANSI/ASHRAE standard 55-2013*. Atlanta, Georgia. www.ashrae.org.

Buikstra, J. E., & Ubelaker, D. H. (Eds.). (1994). *Standards for data collection from human skeletal remains.* Proceedings of a Seminar at The Field Museum of Natural History Organized by Jonathan Haas (Vol. 44). Fayetteville: Arkansas Archaeological Survey.

Coltène Whaledent A. G. (2018) *President Putty Soft instructions for use*. Altstätten: Switzerland. www.coltenewhaledent. com.

Egocheaga, J., Pérez-Pérez, A., Rodríguez, L., Galbany, J., Martínez, L., & Antunes, M. (2004). New evidence and interpretation of subvertical grooves in Neanderthal teeth from Cueva De Sidrón (Spain) and Figueira Brava (Portugal). *Anthropologie, 42(1)*, 49-52.

Epoxy Technology. (2019) *Epo-Tek 301 Instructions for use*. Billerica, MA. www.epotek.com

Fiorenza, L., Benazzi, S, & Kullmer, O. (2009). Morphology, wear and 3D digital surface models: Materials and techniques to create high-resolution replicas of teeth. *Journal of Anthropological Sciences*, *87*, 211-218.

Grine, F.E. & Kay, R.F. (1987). Quantitative analysis of occlusal microwear in Australopithecus and Paranthropus. *Scanning Microscopy*, *1*, 647-656.

Mahoney, P. (2006). Dental microwear from Natufian hunter-gatherers and early Neolithic farmers: Comparisons within and between samples. *American Journal of Physical Anthropology, 130*, 308–319.

Mihlbachler, M.C., Foy, M., & Beatty, B.L. (2019). Surface replication, fidelity and data loss in traditional dental microwear and dental microwear texture analysis. *Scientific Reports, 9*(1), 1595.

Nystrom, P., Phillips-Conroy, J. E. & Jolly, C. J. (2004). Dental microwear in anubis and hybrid baboons (*Papio hamadryas*, sensu lato) living in Awash National Park, Ethiopia. *American Journal of Physical Anthropology, 125*, 279–291.

Polysciences. (2019) *Peel-A-Way Embedding Mold*. Warrington, PA. http://www.polysciences.com

Stynder, D.D., DeSantis, L.R. G., Donohue, S.L., Schubert, B.W., & Ungar, P.S. (2018). A dental microwear texture analysis of the early Pliocene African Ursid Agriotherium africanum (Mammalia, Carnivora, Ursidae). *Journal of Mammalian Evolution*, DOI 10.1007/s10914-018-9436-y.

Teaford, M. F. and Oyen, O. J. (1989). Live primates and dental replication: New problems and new techniques. *American Journal of Physical Anthropology, 80*, 73–81.

Ungar, P.S. (1996). Dental microwear of European Miocene catarrhines: evidence for diets and tooth use. *Journal of Human Evolution, 31*(4), 335-366.

Ungar, P.S., Livengood, S.V., & Crittenden, A.N. (2019). Dental microwear of living Hadza foragers. *American Journal of Physical Anthropology, 169(2)*, 356-367.

Ungar, P.S., & M'Kirera, Francis. (2003). A solution to the worn tooth conundrum in primate functional anatomy. *Proceedings of the National Academy of Sciences, 100*(7), 3874.

Ungar, P. & Williamson, M. (1999). Exploring the effects of tooth wear on functional morphology: A preliminary study using dental topographic analysis. *Palaeontologia Electronica, 3*, 1-18