

# Dimensional Stability of Elastomeric Impression Materials: A Critical Review of the Literature

F.S. Gonçalves\*, D.A.V. Popoff\*, C.D.L. Castro\*, G.C. Silva\*, C.S. Magalhães† and A.N. Moreira‡

**Abstract** - The aim of the present paper was to review the literature concerning the dimensional stability of dental elastomeric impression materials, to support recommendations to control the variables that influence the accuracy of these materials. An electronic search of the Scopus and PubMed databases was performed in November 2010. Articles were selected according to the following inclusion criteria: investigation of the dimensional stability of dental elastomers, an experimental study, sample size reported, laboratory tests described, and published in an English language peer-reviewed journal. The search resulted in 47 articles published between 1958 and 2008; of these, 24 were selected for inclusion in the present study. Great variability was discovered in the experimental methodologies used, such as different working times, temperatures and storage mediums for the impressions, impression techniques, material thicknesses, tray types, and methods of evaluation. Despite the lack of standardization among the studies, this review supports the following recommendations to control the dimensional stability: impressions should be stored at temperatures between  $21 \pm 2$  °C; polyether impressions should be stored in an environment with a relative humidity below 50%; time until pouring has been settled for each elastomer material.

**KEYWORDS:** Dental impression materials, elastomers, physical properties, dental prosthesis, review

## INTRODUCTION

Elastomers are rubber-based materials used in dental impressions that can be classified into four groups according to the polymer constituent: polysulfide (PS), polyether (PE), polyvinyl siloxane (PVS), and condensation silicone (CS). Polysulfides present high tear resistance, good reproduction of details, and low cost. Polyethers exhibit intermediate tear resistance, excellent detail reproduction, and high cost. PVS provides excellent tear strength, a good working time, and excellent elastic recovery, whereas condensation silicones have low tear strength and demonstrate greater distortion<sup>1</sup>.

An ideal impression material should present, among other characteristics, dimensional stability over long periods, which allow the production of precise cast models at any time. However, the materials commonly used in dental impressions present alterations in their dimensional behaviour. The release of water and ethanol as sub-products of the polymerization of polysulfide and condensation silicone, respectively, and polyether hydrophilic behaviour may affect their dimensional stability. Due to the absence of sub-products in PVS polymerization, it presents the most favourable dimensional behaviour<sup>1-5</sup>.

The dimensional changes of the impression materials may affect the quality of fit and retention of dental prostheses, which influence the success of indirect restorative pro-

cedures<sup>4,6-10</sup>. The dimensional behaviour of impression material is influenced by humidity, the time interval from mixing to pouring, and the thickness of the layer of material in the tray<sup>3</sup>. In addition, impression materials contract with the temperature change from the oral cavity to the external environment due to their linear expansion thermal coefficient<sup>9,11</sup>. Volumetric changes are also related to the type of tray, the degree of adhesion between the tray and materials, and the type of polymer comprising the elastomers<sup>11</sup>. The impression technique can be performed using single or double steps, which can lead to different outcomes with respect to the dimensional accuracy<sup>8,12</sup>.

Given the many variables that can influence the stability of impression materials, the present study aimed to review the current English dental literature for experimental studies related to elastomeric materials and to propose clinical recommendations for the control of variables that influence the accuracy of these materials.

## METHODS

An electronic search was conducted in November 2010 using the Scopus and PubMed databases and the following search terms alone and in combination: elastomeric impression material and dimensional stability; elastomeric impression material and time; dimensional stability and working time; elastomeric impression material, dimensional stability and working time. The abstracts of the articles were retrieved, reviewed, and sorted based on the following inclusion and exclusion criteria. Inclusion criteria: experimental study investigating the accuracy of dental impression elastomeric materials, sample size reported, laboratory tests described, and published in an English

\* DDS, MS

† DDS, MS, PhD

‡ DDS, PhD

language peer-reviewed journal. Exclusion criteria: studies analyzing the relationship between disinfection modes and dimensional stability.

## RESULTS

The search resulted in 47 articles that were published between 1958 and 2008, and 24 in vitro studies were selected based on the inclusion criteria. Table 1 shows the included studies according to the materials, test variables, sample size and experimental testing for the period from 1958 to 2008.

## DISCUSSION

Elastomers are susceptible to permanent deformation, which explains the lack of uniformity observed in the impressions with deformation related to the inability of the materials to return entirely to their original dimensions. The elastic recovery capacity is different among the materials, and it is an important factor in the outcome of impressions. Although no impression material presents 100% elastic recovery, PVS is indicated as the material with a better elastic recovery capacity<sup>1-5</sup>.

The studies varied considerably with respect to the test design, test variables, and materials evaluated. Although some selected studies included the irreversible hydrocolloid in their experiments, the present review considered only those findings related to elastomers because these are the materials of choice for the final impression in restorative dentistry. Furthermore, the disinfection of dental impressions, which should be performed as a routine procedure for the control and prevention of cross-infection, is another important factor related to the dimensional stability of elastomers<sup>1,13</sup>. However, the guidelines regarding disinfection procedures include numerous combinations of impression materials, disinfectant solutions, methods and periods of application and should be examined in detail independently of the variables evaluated in the present review. Recently, another review was published concerning this matter<sup>13</sup>.

The methods applied to evaluate the dimensional stability of impression materials were as follows: direct measurement of the impressions<sup>14-17,27</sup>, comparison between master models and plaster models<sup>4,6,8-10,18,19,26</sup>, and evaluation of the fit of restorations in plaster models<sup>2,3,5,7,8,11,12,20-24</sup>. In the latter two methods, it is necessary to elaborate a master model, which is usually metallic with a polished surface, according to specification number 19 of the American Dental Association (ADA)<sup>25</sup>. Master models of acrylic have been used as an alternative to the metal patterns, whereas the use of natural teeth remains uncommon<sup>4,12</sup>. Measuring impressions may be advantageous, as it restricts the materials involved and permits a more precise view of the phenomena under study. Measurements on casts simulate the clinical and laboratory practice although they complicate the experimental procedure<sup>13</sup>. Variations in temperature and humidity, which are common in dental practice, influence the dimensional stability of elastomeric impression materials. Several authors have simulated the conditions of temperature and humidity that are found in clinical practice. Some of them used 37° C,<sup>4,5,12,17,22</sup> others 35° C<sup>26</sup>, and some followed specification number 19 of the ADA, which considers 32° C<sup>2,14,18,27</sup>. Such differences in the temperature values used in these studies are justified by

the variety of climatic conditions. Corso *et al.*<sup>15</sup> evaluated the behavior of polyether and PVS in the storage temperature used for the impressions (4, 23 and 40° C), whereas Pant *et al.*<sup>17</sup> evaluated the behaviour of PVS impressions by varying the temperature between 21 ± 2° C and 37° C. Greater dimensional changes were observed for impressions that were stored at higher temperatures. These results suggested that PVS and polyether impressions should be stored at 21 ± 2 ° C<sup>15,17</sup>.

With respect to humidity, some studies have used atmospheric air as the storage medium for the impression, whereas Endo and Finger<sup>20</sup> simulated the storage of polyether impressions in environments with a relative humidity of 0% (silica gel), 33% (MgCl<sub>2</sub>·6H<sub>2</sub>O), 50% (Ca(NO<sub>3</sub>)<sub>2</sub>·4H<sub>2</sub>O), 75% (NaCl), and 100% (deionized water). The authors observed that the higher the humidity, the greater is the deformation due to hygroscopic expansion of the material. A relative humidity of up to 50% has been recommended for the storage of polyether impressions regardless of the storage medium. Kanehara *et al.*<sup>3</sup> also evaluated different storage mediums for polyether and PVS impressions: 0% (silica gel), 50% (Ca(NO<sub>3</sub>)<sub>2</sub>·4H<sub>2</sub>O) and 100% (deionized water). Significant dimensional changes were only observed for polyether depending on the storage medium, and the authors agreed with the recommendation proposed by Endo and Finger<sup>20</sup> that polyether impressions should be stored in an environment containing up to 50% humidity. The results showed that humidity may affect the dimensional stability of the impressions, and the storage condition should be specified by the elastomers manufacturers<sup>3,6,21</sup>.

The thickness of the elastomers used in the tray may also be an important factor related to the stability of the materials, although few studies analyzed this hypothesis. Schenell and Phillips<sup>23</sup> used material thicknesses of 0.5, 2.0, and 4.5 mm, and they observed an increase in the misfit of restorations with greater material thicknesses. Basset *et al.*<sup>11</sup> used thicknesses of 1.25 to 3 mm and obtained the best results with trays that allowed a thin layer of material. Both studies recommended a thickness of 1.5 to 2.0 mm to minimize dimensional changes of the materials.

Several techniques and different types of trays to make impressions have been described, and these two factors contribute to the dimensional behaviour of elastomers. The trays can be standard (stock) or personalized, perforated or not, and the results are inconsistent regarding these variables<sup>2,26</sup>. The results regarding the best impression technique are also controversial. Stackhouse Jr.<sup>12</sup> evaluated polysulfides and condensation silicones and found no significant differences between the techniques of a single stage or two stages. Schenell and Phillips<sup>23</sup> demonstrated the superiority of the two-stage technique using polysulfide. Henry and Harnist<sup>8</sup> observed increased models obtained from polysulfide and polyether impressions generated using the one-step technique.

Various combinations of impression materials and storage time have been found.<sup>2-12, 14-24, 26-28</sup> The time until pouring ranges from immediately after mouth removal to 13 weeks. It has been indicated that the impression should be poured between 30 minutes and 8 days for polysulfides, 30 minutes to 14 days for polyether, 30 minutes to 3 days for condensation silicone, and 30 minutes to 21 days for PVS<sup>3-6,9-12,14,15,17,19,21,23,24,26,27</sup>.

**Table 1.** Included studies based on Scopus and Medline searches performed in April 2010, considering the materials, variables, sample size, and experimental testing during the period from 1958-2008.

<i>Author (year)</i>	<i>Materials*</i>	<i>Study variables</i>	<i>Sample size</i>	<i>Experimental test</i>
Schenell (1958) <sup>23</sup>	AL, PS	-Material thickness -Storage environment	N = 4 models	Microscopic evaluation of restoration fit
Myers (1960) <sup>22</sup>	AL, PS, CS	-Impression technique -Storage time -Time of manipulation	N= 10 models	/Restoration fit evaluated by digital pressure
Basset (1969) <sup>11</sup>	AL, PS, CS	-Types of trays -Storage time -Thickness of material	N= 12 models	Restoration fit evaluated by digital pressure
Stackhouse (1970) <sup>19</sup>	PS, CS	-Storage time -Impression technique	N= 10 models	Microscopic measurement of models
Henry (1974) <sup>7</sup>	PS, PE, CS	-Storage time -Impression technique	N= 10 models	Microscopic measurement of models and restoration fit evaluated by digital pressure
Hembre Jr. (1974) <sup>7</sup>	PS, PE, CS	-Storage time	N= 10 models	Microscopic evaluation of restoration fit
Sawer (1974) <sup>9</sup>	PS, PE, CS	-Storage time	N= 5 models	Microscopic measurement of models
Stackhouse (1975) <sup>12</sup>	AL, PS PE, CS	-Storage time	N= 2 models (first pouring), N = 3 (second pouring)	Restoration fit and microscopic evaluation of diameter alterations of dies
Eames (1979) <sup>2</sup>	PS, PE, CS	-Storage time	N= 10 models	Microscopic evaluation of restoration fit
Marcinack (1980) <sup>4</sup>	AL, PS PE, CS	-Storage time	N= 3 models	Microscopic measurement of models
Ciesco (1981) <sup>14</sup>	PE, CS, PVS	-Storage time -Types of trays	N= 5 impressions	Microscopic measurements of impressions
Clancy (1983) <sup>27</sup>	PE, CS, PVS	-Storage time	N= 75 impressions	Computerized microscopic measurements of impressions
Williams (1984) <sup>5</sup>	PS, PE CS, PVS	-Storage time	N= 5 models	Microscopic evaluation of restoration fit
Johnson (1985) <sup>18</sup>	PS, PE CS, PVS	-Storage time -Types of Trays	N= 3 models (4 h and 24 h) N= 5 models (1 h)	Microscopic measurement of models
Tjan (1986) <sup>24</sup>	AL, PS, PE CS, PVS	-Storage time -Types of restorations	N= 5 models	Microscopic evaluation of restoration fit
Corso (1998) <sup>15</sup>	PE, PVS	-Storage time -Types of Trays -Temperature storage	N= 6 impressions	Microscopic measurements of impressions
Thomgthammachat (2002) <sup>28</sup>	PE, PVS	-Storage time -Types of trays	N= 5 models	Microscopic measurement of models
Sha (2004) <sup>10</sup>	PE, PVS	-Storage time	N= 10 models	3D laser scanning measurements of models
Chen (2004) <sup>6</sup>	AL, CS, PVS	-Storage time	N= 10 models	Digitized photomicrograph measurements of models
Kanehira (2005) <sup>3</sup>	PE, PVS	-Storage time -Storage environment	N= 6 models	Restoration fit evaluated by a displacement sensor
Endo (2006) <sup>20</sup>	PE, PVS	-Storage time -Storage environment -Temperature of impression attainment	N= 6 models	Restoration fit evaluated by a displacement sensor
Holst (2007) <sup>16</sup>	PE, PVS	-Storage time	N= 71 implants impressions	Microscopic measurements of impressions and 3D imaging
Franco (2007) <sup>21</sup>	PE, PVS	-Storage time	N= 60 models	Microscopic evaluation of restoration fit
Pant (2008) <sup>17</sup>	PVS	-Storage time -Temperature storage	N = 5 impressions	Measurements of models using a computerized imaging system and scanning electron microscopy

\* The tested materials are abbreviated as follows: AL alginate; PS polysulfide; PE polyether; CS condensation silicone; PVS polyvinyl siloxane.

Dimensional changes have been observed in polysulfide impressions over time, and a short period (30 minutes) is recommended to obtain the gypsum model<sup>4-5,7,9,21,23,27</sup>. The polymerization of polysulfide is initiated by an increase in chain and cross-links between the free sulfur-hydrogen groups present on the basic molecule, and this process is triggered by the presence of lead dioxide. This reaction occurs via condensation and releases water as a sub-product. The evaporation of water molecules from the impression surface results in distortion, which affects the dimensional stability of the polymerized material<sup>1</sup>.

Dimensional changes have been observed in condensation silicone impressions at all evaluated times. There is a

consensus that condensation silicone impressions should not be stored for more than 30 minutes following removal from the mouth<sup>4-5,7,9,21,23,27</sup>. The production of ethanol as a sub-product of the polymerization and its evaporation likely affect the dimensional stability of the material<sup>1</sup>.

Polyether polymerizes via a reaction between the aziridine rings located at the end of the branch of its own molecules, and cross-linking is initiated by an aromatic ester sulfonate. In this reaction, no sub-products are released, which favours the dimensional stability of the impression. However, unlike other materials, the high hydrophilic characteristic of polyether can lead to the absorption of water from the atmosphere and from the storage medium.<sup>1</sup>

This material shows a greater stability over time when compared to polysulfide and condensation silicone, despite controversy regarding the time of pouring: immediate or periods of up to 24 hours<sup>3,12,21,26</sup>, 1 week<sup>14,24</sup>, or 4 weeks<sup>27</sup>.

The polymerization of PVS occurs without the release of a sub-product, i.e., the material presents less dimensional change and is therefore considered stable<sup>3,5,20,21,24,26,27</sup>. However, a secondary reaction that occurs during the polymerization can lead to the formation of hydrogen, which may cause pores in plaster models that are poured immediately after removal from the mouth. PVS showed superior dimensional stability compared to polyether and condensation silicone, and it has been suggested that impressions may be poured up to 4 weeks<sup>26-27</sup>.

Great variability was observed in the methodologies used in the reviewed studies. The lack of standardization of variables in the study designs delays the development of recommendations that could be used routinely by professionals. The most consistent recommendation stated in the reviewed articles was that gypsum models should be obtained from elastomers impressions within 30 minutes<sup>2,5,16,18-19,27</sup>.

Although there have been attempts to simulate the clinical reality in laboratory studies, the lack of standardization and the diversity of factors involved preclude a comparative statistical analysis of the results obtained in the different studies. Therefore, a systematic review of the experiments, which could improve our understanding of the dimensional behaviour of elastomers over time, was not possible.

## CONCLUSIONS

This review supports the following recommendations to control the dimensional stability of elastomeric impression materials:

- Impressions should be stored in an environment with temperatures of  $21 \pm 2^\circ \text{C}$ .
- There was no consensus regarding the optimal storage medium for elastomers, except for the polyether, which should be stored in an environment with a relative humidity of less than 50%.
- Polysulfide and condensation silicone impressions should be poured up to 30 minutes.
- Polyether impressions can be poured between 30 minutes and 24 hours.
- PVS impressions can be poured between 30 minutes and 4 weeks.

## ADDRESS FOR CORRESPONDENCE

Guilherme C Silva, Av Afonso Pena 4334, Belo Horizonte, MG, Brazil, 30130-009. Email: guilhermeccs@ufmg.br

## REFERENCES

1. Donovan, T.E. and Chee, W.W. A review of contemporary impression materials and techniques. *Dent. Clin. N. Am.*, 2004; **48**:445-470.
2. Eames, W.B., Wallace, S.W., Suway, N.B. and Rogers, L.B. Dimensional accuracy and stability of elastomeric impression materials. *J. Prosthet. Dent.*, 1979; **42**:159-162.
3. Kanehira, M., Finger, W.J. and Endo, T. Volatilization of components from and water absorption of polyether impressions. *J. Dent.*, 2005; **34**:134-138.
4. Marcinack, C.F., Young, F.A., Draughn, R.A. and Fleming, W.R. Linear dimensional changes in elastic impression materials. *J. Dent. Res.*, 1980; **59**:1152-1155.
5. Williams, P.T., Jackson, D.G. and Bergman, W. An evaluation of the time-dependent dimensional stability of eleven elastomeric impression materials. *J. Prosthet. Dent.*, 1984; **52**:120-125.
6. Chen, S.Y., Liang, W.M. and Chen, F.N. Factors affecting the accuracy of elastomeric impression materials. *J. Dent.*, 2004; **32**:603-609.
7. Hembree, J.H.Jr. Comparative accuracy of elastomer impression materials. *J. Tenn. Dent. Assoc.*, 1974; **54**:164-167.
8. Henry, P.J. and Harnist, D.J. Dimensional stability and accuracy of rubber impression materials. *Aust. Dent. J.*, 1974; **19**:162-166.
9. Sawyer, H.F., Dilts, W.E., Aubrey, M.E. and Neiman, R. Accuracy of casts produced from the three classes of elastomer impression materials. *J. Am. Dent. Assoc.*, 1974; **89**:644-648.
10. Shah, S., Sundaram, G., David, B. and Sherriff, M. The use of a 3D laser scanner using software superimpositional to assess the accuracy of impression techniques. *J. Dent.*, 2004; **32**:653-658.
11. Bassett, R.W., Vander Heide, J.D. and Smith, D.D. Clinically oriented tests comparing accuracy of elastic impression materials. *J. South. Calif. Dent. Assoc.*, 1969; **37**:47-57.
12. Stackhouse, J.A.Jr. A comparison of elastic impression materials. *J. Prosthet. Dent.*, 1975; **34**:305-313.
13. Kotsiomiti, E., Tziialla, A. and Hatjivasilou, K. Accuracy and stability of impression materials subjected to chemical disinfection - a literature review. *J. Oral. Rehabil.*, 2008; **35**:291-299.
14. Ciesco, J.N., Malone, W.F., Sandriko, J.L. and Mazur, B. Comparison of elastomeric impression materials used in fixed prosthodontics. *J. Prosthet. Dent.*, 1981; **45**:89-94.
15. Corso, M., Abanomy, A., Di Canzio, J., Zurakowski, D. and Morgano, S.M. The effect of temperature changes on the dimensional stability of polyvinyl siloxane impression materials and polyether. *J. Prosthet. Dent.*, 1998; **79**:626-631.
16. Holst, S., Blatz, M.B. and Gorriner, M. Influence of impression material and time on the three-dimensional accuracy of implant impressions. *Quintessence Int.*, 2007; **38**:67-73.
17. Pant, R., Andrzej, S., Robert, K.F. and David, R.R. Long-term dimensional stability and reproduction of surface detail of four polyvinyl siloxane duplicating materials. *J. Dent.*, 2008; **36**:456-461.
18. Johnson, G.H. and Craig, R.G. Accuracy of four types of rubber impression materials compared with time of pour and repeat the pour of models. *J. Prosthet. Dent.*, 1985; **53**:484-490.
19. Stackhouse, J.A.Jr. The accuracy of stone dies made from rubber impression materials. *J. Prosthet. Dent.*, 1970; **24**:377-386.
20. Endo, T. and Finger, W.J. Dimensional accuracy of a new polyether impression material. *Quintessence Int.*, 2006; **37**:47-51.
21. Franco, E.B., da Cunha, L.F. and Benetti, A.R. Effect of storage period on the accuracy of elastomeric impression. *J. Appl. Oral. Sci.*, 2007; **15**:195-198.
22. Myers, G.E. and Stockman, A.B. Factors that affect the dimensional stability and accuracy of the mercaptan rubber-base impression materials. *J. Prosthet. Dent.*, 1960; **10**:525-535.
23. Schenell, R.J. and Phillips, R.W. Dimensional stability of rubber base impressions and certain other factors affecting accuracy. *J. Am. Dent. Assoc.*, 1958; **57**:39-48.
24. Tjan, A.H., Whang, S.B., Tjan, A.H. and Sarkissian, R. Clinically oriented evaluation of the accuracy of commonly used impression materials. *J. Prosthet. Dent.*, 1986; **56**:4-8.
25. American Dental Association. Revised specification No. 19 for non-aqueous, elastomeric dental impression materials. *J. Am. Dent. Assoc.*, 1977; **94**:733-741.
26. Thongthammachat, S., Moore, B.K., Barco, M.T., Hovijitra, S., Brown, T.A. and Andres, C.J. Dimensional accuracy of dental casts: influence of tray material, impression material, and time. *J. Prosthodont.*, 2002; **11**:98-108.
27. Clancy, J.M., Scandrett, F.R. and Ettinger, L.G. Long term dimensional stability of three current elastomers. *J. Oral. Rehabil.*, 1983; **10**:325-333.
28. Hosoda, H. and Fusayama, T. Distortion of irreversible hydrocolloid and mercaptan rubber-base impressions. *J. Prosthet. Dent.*, 1961; **11**:318-333.