JOURNAL OF THE MECHANICAL BEHAVIOR OF BIOMEDICAL MATERIALS 29 (2014) 295–308

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Review Article

Thermal cycling for restorative materials: Does a standardized protocol exist in laboratory testing? A literature review

Anna Lucia Morresi[a], *Maurizio D'Amario*[a,*], *Mario Capogreco*[a], *Roberto Gatto*[b], *Giuseppe Marzo*[b], *Camillo D'Arcangelo*[c], *Annalisa Monaco*[b]

[a]*Unit of Restorative Dentistry, Oral Pathology, Department of Life, Health and Environmental Sciences, School of Dentistry, University of L'Aquila, L'Aquila, Italy*
[b]*Department of Life, Health and Environmental Sciences, School of Dentistry, University of L'Aquila, L'Aquila, Italy*
[c]*Unit of Restorative Dentistry, Department of Oral Science, Nano and Biotechnology, "G. D'Annunzio" University of Chieti, Italy*

ARTICLE INFO

Article history:
Received 12 July 2013
Received in revised form
15 September 2013
Accepted 21 September 2013
Available online 27 September 2013

Keywords:
Aging
Dental restorations
In vitro tests
Standardization
Thermal cycling.

ABSTRACT

In vitro tests continue to be an indispensable method for the initial screening of dental materials. Thermal cycling is one of the most widely used procedures to simulate the physiological aging experienced by biomaterials in clinical practice. Consequently it is routinely employed in experimental studies to evaluate materials' performance. A literature review aimed to elucidate test parameters for in vitro aging of adhesive restorations was performed. This study aims to assess whether or not a standardized protocol of thermal cycling has been acknowledged from a review of the literature. An exhaustive literature search, examining the effect of thermal cycling on restorative dental materials, was performed with electronic database and by hand. The search was restricted to studies published from 1998 to August 2013. No language restrictions were applied. The search identified 193 relevant experimental studies. Only twenty-three studies had faithfully applied ISO standard. The majority of studies used their own procedures, showing only a certain consistency within the temperature parameter (5–55 °C) and a great variability in the number of cycles and dwell time chosen. A wide variation in thermal cycling parameters applied in experimental studies has been identified. The parameters selected amongst these studies seem to be done on the basis of convenience for the authors in most cases. A comparison of results between studies would appear to be impossible. The available data suggest that further investigations will be required to ultimately develop a standardized thermal cycling protocol.

*Correspondence to: Unit of Restorative Dentistry. Oral Pathology, Department of Life, Health and Environmental Sciences, School of Dentistry, University of L'Aquila, Via Vetoio, Delta 6, 67010 Coppito, L'Aquila, Italy. Tel.: +39 862 434 785; fax: +39 0862 434 978.
E-mail address: mauriziodamario@gmail.com (M. D'Amario).

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http://dx.doi.org/10.1016/j.jmbbm.2013.09.013

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1. Introduction

Over the last few decades, significant improvements have been made in the field of dental materials, so actually modern restorative dentistry can count on a wide range of materials used for dental rehabilitations.

The long term success of modern dental restoratives is limited by their durability in the oral environment (Freeman et al., 2012). Longevity and efficiency are characteristics that should ideally be provided from each product; however, these properties are still goals to be achieved.

Restorative materials must withstand a harsh environment, which varies from patient to patient. Mastication forces, occlusal habits, dietary factors, humidity and temperature fluctuations all contribute to uncontrollable factors that may affect materials longevity (Cavalcanti et al., 2007).

For the evaluation of dental materials, well-conducted randomized controlled clinical trials are considered the best method to evaluate the quality of new systems; nevertheless there are many limitations that do not allow this kind of study to be routinely employed (Nikaido et al., 2002; Rocha et al., 2007; Koyuturk et al., 2008). First, factors such as operator variability, substrate differences, patient compliance and recall failure make these tests complicated and their standardization impossible (Nikaido et al., 2002). Second, clinical trials are costly and time-consuming, so in adopting the view that dental materials evolve rapidly, it is very important to understand that their clinical success must be estimated in an easy, rapid and realistic way (Koyuturk et al., 2008; Naumann et al., 2009).

In vitro simulations can be useful to predict the longevity of dental materials, evaluating their mechanical and structural decay characteristics during clinical aging.

Although laboratory evaluation and in vitro studies cannot exactly simulate conditions in the oral cavity, such as the clinical environment, moisture and stresses inflicted on teeth and restorations alike, they can, to some extent, simulate the oral cavity environment through aging procedures of teeth and/or restorations. As a result, it appears that experimental studies are, as far as possible, similar to the outcomes obtained in clinical situations under complex occurrences in the oral cavity (Khoroushi and Mansoori, 2012).

Many researchers are agreed, that while static tests can obtain data over a longer time scale than that of mastication, it can be a source of misleading results. Dynamic tests appear to better mimic the cyclic masticatory loading to which dental composites are clinically subjected which could be extremely valuable in predicting biomaterials clinical performance when working under the cyclic solicitations generated by the human body's physiological movements (Mesquita and Geis-Gerstorfer, 2008; Mazzitelli et al., 2012).

In the field of laboratory research, out of the currently available systems able to reproduce dynamic stresses, thermal cycling is one the most widely used procedures that is also widely accepted in international literature.

Many experimental studies have been published that use thermal cycling regimes to test dental materials characteristics (Doerr et al., 1996; Schuckar and Geurtsen, 1997; Wegner et al., 2002; Bedran-de-Castro et al., 2004b; D'Amario et al., 2010), following the publication of Gale and Darvell's review over ten years ago (Gale and Darvell, 1999). The aim of the subsequent review is to assess whether or not there is a standardized protocol for thermal cycling processes, through the appraisal of specific experimental studies published in the last fifteen years.

2. Materials and methods

The following review was conducted using the following search strategy: MEDLINE database (via PubMed) was searched between January 1998 and August 2013 by a single reviewer. Key words used were: (thermal cycling OR thermocycling OR aging system) AND (dentistry OR restorative dentistry). In addition, the following journals were manually searched between January 1998 and August 2013: Operative Dentistry, Journal of Prosthetic Dentistry, Dental Materials, Journal of Dentistry, Journal of Endodontics, Journal of Applied Oral Science, Journal of Adhesive Dentistry. No language restriction was applied.

2.1. *Study inclusion and exclusion criteria*

One reviewer performed the study selection process in three phases. In the first stage, the studies were analyzed on the basis of the title and abstract. Only studies of general interest for the review were admitted to the next phase. In the second phase, the studies were analyzed according to the following inclusion criteria (A):

A.1 Experimental studies.
A.2 Studies involving materials used in restorative dentistry.
A.3 Available abstract.