The effect of mixing methods on dynamic viscoelastic change of a temporary soft lining material, Coe-Comfort®

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The effect of mixing methods on dynamic viscoelastic change of a temporary soft lining material, Coe-Comfort®

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Ryu, Hyun Ju

Table of Contents

List of Figures and Tables

English Abstract

The effect of mixing methods on dynamic viscoelastic change of a temporary soft lining material, Coe-Comfort®

Temporary soft lining materials used extensively for the purposes of tissue conditioning and functional impression would show different properties according to not only the powder to liquid ratio but also the degree of void entrapment, which would in turn affect on the viscoelasticity of the material and on the period of maintaining softness. The temporary soft lining material Coe-Comfort®(Coe Lab., Illinois, USA) was mixed to prepare the specimens used in the study using different methods of mixing that could affect on the degree of void entrapment such as hand mixing, machine mixing using an impression material mixer, and vacuum treated mixing. Then, the change in specimen thickness was measured and compared when the specimens were exposed to dynamic load considering the mastication cycle in order to compare the deformation pattern on dynamic load according to different mixing methods.

Ten specimens were prepared with each mixing method and kept in distilled water. Dynamic load of 2Hz for 1 minute was applied time serially by 2 h, 12 h, 1 day, 2 day and 3 day after mixing and the change in thickness was measured in real time. After simple linear regression analysis was performed with the measured values recorded within initial 30 seconds, two-way ANOVA test was done on the steepness according to the mixing method and storage time.

The results of analysis showed no difference in the pattern of deformation according to mixing methods ($p>0.05$) and no significant differences between increased storage time and deformation on load in all 3 groups (*$p>0.05$*). The limitations of the present study were storage solution being distilled water and short exposure time. The degree of change in the thickness of Coe-Comfort® according to dynamic load was not affected significantly by mixing methods provided that the powder to liquid ratio was constant. More studies are needed in the future on analyzing the effects using the degree of void entrapment as a single factor and on the comparison of test design and various soft lining materials considering similar clinical conditions such as storage solution, storage temperature, and cycle and time of applying load.

Key words : temporary soft relining material, mixing method, dynamic load, viscoelasticity

The effect of mixing methods on dynamic viscoelastic change of a temporary soft lining material, Coe-Comfort®

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Introduction

Soft lining materials can be defined as compliant, viscoelastic materials used to improve the health of abused denture-bearing tissue and make functional impressions. According to the purpose of their use, soft lining materials are divided into temporary soft lining materials and the long term soft lining materials(Jagger, 1997). Temporary soft lining materials can be used as tissue conditioner or lining materials and should distribute more evenly and absorb the functional and nonfunctional forces by means of cushioning effect(Murata, 1998). So the materials need to show viscoelastic properties in that they should flow under steady pressure but be resilient under dynamic forces such as chewing. To reach a easy understanding of the viscoelasticity which is a compound word, it seems that the elastomer can be compared to a spring and the viscomer to a dashpot(Dental materials, 2001). The materials that we are to discuss is temporary soft lining materials which has the combined characteristics of both. It can be applied for diverse use according to the proportion of each property. However, the temporary soft liners that contain plasticizer which tends to leach out are not stable in an aqueous environment such as the oral cavity(Saber-sheikh, 1999; Graham, 1989), and its consistency is not easy to manipulate with the properties that cannot be retained for a certain period of time. Therefore, several studies about the property of soft liner have been tried to solve these problem. For the maintenance of softness, resiliency or viscoelasticity, some experiments on storage environments, thickness of liner, force of mastication, and coating materials have been reported(Malmström, 2002). Generally, it is suggested to follow the manufacturers′ recommendations for liquid to powder ratios, timing of manipulation, and insertion of materials(Graham, 1989). Nevertheless, for the controlling of the consistency to be clinically more applicable use, many experiments that altered related factors have been reported, such as changing powder/liqid(Murata, 2001), adding different plasticizer(Mack, 1989), using thermocycling(Murata, 2000) etc. But there was no coincidence in its ideal property for diverse mucosal states and a recognized method to determine the property. In other words, their results indicated that materials should be selected in accordance with the specific clinical purpose (Malmström, 2002) and clinicians should control the consistency to fulfil clinical requirements.

When we consider that the setting reaction of temporary soft lining material, after the powder and liquid are mixed together to form a slurry, it is a physical not a chemical process, with the liquid penetrating the powder particles to form a gel. So we hypothesized that changing the physical factors such as whether inclusion of voids by mixing methods affects the setting reaction and that a difference in consistency and maintenance will exist. In the case of other mixing methods such as vacuum-treated Visco-Gel® tissue conditioner, there was a difference in the size and number of voids and it produced a denser, less porous gel and improved surface texture.(Nimmo, 1985)

In order to develop a clinically relevant test for temporary soft lining materials, it is necessary to consider the wide range and nature of the applied forces as well as changes which occur over time (Murata, 2000) and to monitor the change in property in loading dynamic force like intraoral condition. The reason of this is, through the Graham's study on change of flexibility during simulated chewing, that the resilient lining material under a static stress may behave in clinical function as if it were a more rigid material and consequently transmit more of the applied occlusal load to the underlying tissues. Under the presupposition of above conditions, the ways to better manipulate temporaty soft lining material with higher reproducibility and without changing its chemical components were studied.

The purpose of this study were to determine whether different mixing methods(hand mixing, machined mixing using impression material mixer, and vacuum treated mixing) have effects on the viscoelasticity of Coe-Comfort® which is one of the typical temporay soft lining materials under dynamic load.

Materials and Methods:

The material used in this study was the acrylate-based denture polymer, Coe-Comfort®(Coe Laboratories inc. Illinois. USA) which consists of polymethylmethacrylate, ethyl alcohol, dibutyl phthalate, Zinc oxide undecylenate. (Fig.1) This was quantified using an electronic scale (OHAUS/SD-2020, U.S.A.) and micropipet (PIPETMAN, Gilson Co., France) as 6 gm powder to 5 cc liquid and then was mixed by three different methods for 12 seconds. First, as a control group, materials were mixed manually. the second was machined mixing using impression material mixer (MIGMA mixer, MIKRONA, Swiss)(Fig.2). The third was a vacuum treated mixing using bell jar with a vacuum source under 170 cmHg negative pressures(Kolno, Gunheung, KOREA)(Fig.3). Immediately after mixing, it was poured to plastic caps (22mm internal diameter × 5mm height with a bottom of 2mm thickness). By repeating above process, 10 specimens per each three different mixing methods were prepared in the shape of 3mm thick soft liner disks . (Fig.4)

Prior to the first measurement, specimens had been stored in distilled water for 2 hours 25℃ atmosphere and the distilled water was replaced everyday during testing period. Specimens were replaced in the distilled water immediately after each measurement. The measurements of the thickness of specimen under dynamic load carried out at 2h, 12h, 24h, 48h, 72h after the mixing.

The deformation properties of test materials under the dynamic load were determined by the change of thickness using custom made automatic compressive load applicator(FM Korea Co, Seoul, Korea)(Fig.5). The load applicator is composed of a vertical arm, and a horizontal arm connected to the upper portion of it. The vertical arm applies load on the specimen by direct contact and the horizontal arm performs an up and down hinge movement by a motor-attached bar, resulting in a sinusoidal application of load on specimens by the vertical arm. Namely it works by the mechanism that when the horizontal arm is completely raised by the motor, zero pressure is put on the specimen, and when the bar is at its lowest position, the horizontal arm loses all support thus putting on its complete weight on the specimen. Equipments used in this investigation was described precisely in Fig.5. During the testing period, the specimen was positioned between the dynamic moving vertical arm of load applicator and fixed testing plate, and a sinusoidal load was applied as a forced power to the specimen (2Hz, for 1 minute) The changing thickness of specimens under the dynamic load was measured immediately with a measuring equipment LVDT, linear velocity displacement transducer, (GT2500, RDP Electronics Ltd. Grove St.Wolverhampton, UK) which was connected to the lateral wing of vertical arm of load applicator. The output voltages were conditioned and recorded by connecting PC. The sampling frequency was set at 3 times per second. A LVDT, AD converter and a conditioning module were calibrated before experiment for reliable output. The acquired data were recorded with a specially written program

(SYHAD911) which can acquire up to three channel and adjust sampling rates. A series of measurement was conducted at the following times after specimen preparation: 2h, 12h, 1day, 2day, 3day.

To examine the viscoelastic behavior of Coe-Comfort® under the dynamic load, accumulated deformation was predicted from the maximum deformation points recorded during initial 30 seconds using simple linear regression analysis(Fig.6) The null hypothesis dealt with was whether accumulated deformation rate, as expressed the slope from the linear regressions, is affected with the effect of mixing methods along the storage periods. In addition, the effects of storage period was also examined within each mixing method group. Each set of data were examined with two-way ANOVA and the *Bonferroni test* with the use of SPSS software(SPSS Ver.11, Inc., Chicago, IL, USA). The *Bonferroni test* was *t-tests* to perform pairwise comparisons between group means. The observed significance level is adjusted for the fact that multiple comparisons are being made.

Fig.1

Fig.2

Fig.1. Test material: Coe-Comfort®

Fig.2. Impression material mixer (MIGMA mixer, MIKRONA, Swiss)

Fig.3

Fig.4

Fig.3. Bell jar with a vacuum source (Kolno, Gunheung, KOREA).

Fig.4. Test specimen: Acrylic cap used as a mold for Coe-Comfort®

Fig.5. Automatic compressive load applicator (FM Korea Co, Seoul, Korea): Frontal view with signal condition for LVDT

Data & Results

In order to deduct the change of viscoelasticity of Coe-Comfort®, which can be elicited by the amount of deformation in thickness per unit time under the dynamic load, we compared the residual thickness of each specimen as the aging time. Because the aging of the material is a time dependant process, the accumulated deformation was predicted from the maximum deformation points recorded during initial 30 seconds using simple linear regression analysis(Fig.6). The linear regression of all raw data were plotted according to the mixing methods and the storage time(Fig.7) and the mean value and deviation of each group were demonstrated in Fig.8. As a results of this study, changes in the viscoelastic property of Coe-Comfort® were characterized by slight and continuous reduction in the three different mixing method and the thickness of the specimen varied according to the storage time with no specific tendency. All of the specimens underwent a reduction in thickness during 3 days. Reduction in thickness were generated by cumulative effect of dynamic load and aging process. The relationship between deformation and the measuring time, during initial 30 seconds, showed a inverse correlation, but during the rest of 30 seconds of the testing time, there was no significant changes in the deformation.

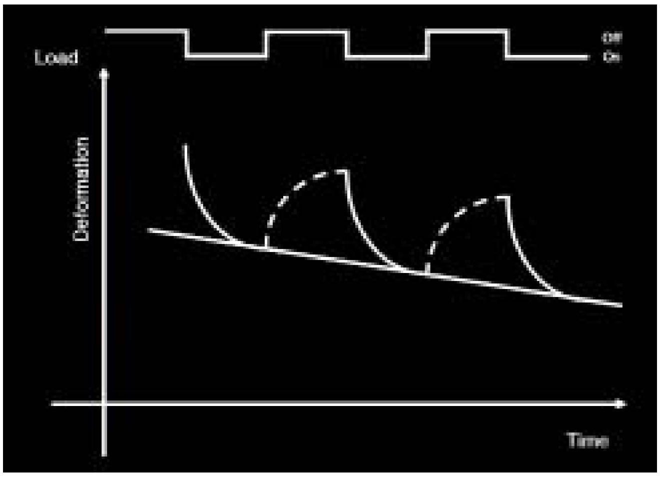

Fig.6. Deformation versus Time graph used for simple linear regression analysis(straight line) under the dynamic load.

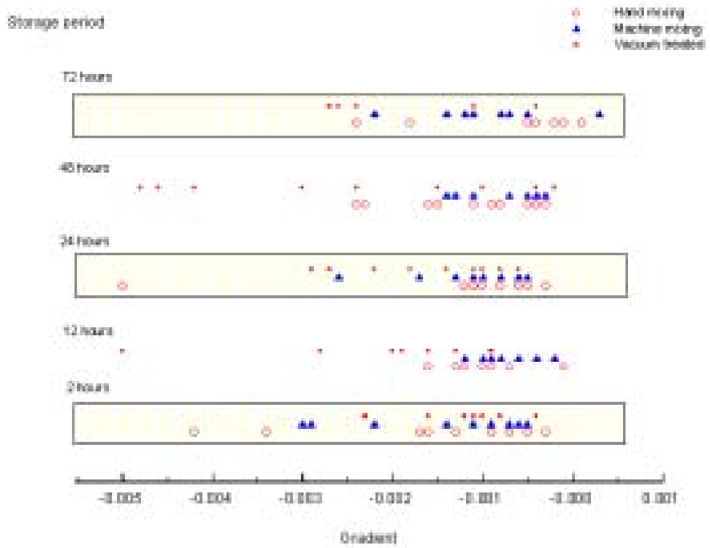

Fig.7. Scatter plot representing the gradient value from linear regression analysis grouped by mixing method and storage time.

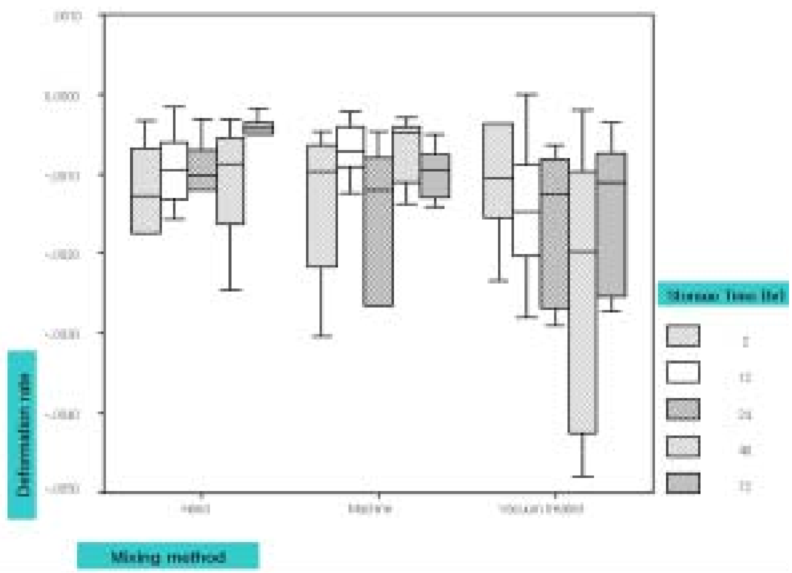

Fig.8. Box-Whisker plots of deformation rate(mm/sec): The mean value and deviation of each mixing group

Table 1. Levene's Test of Equality of Error Variances to examine the assumption of two-way ANOVA analysis

F	df1	df2	Sig.
2.068	8	36	0.066

Table 2. The results of a two-way analysis of variance for analyzing two factors: mixing methods(MIXING) and storage period(TIME)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.947E-06	8	9.933E-07	2.083	0.064
MIXING	3.383E-06	2	1.692E-07	0.355	0.704
TIME	3.365E-06	2	1.683E-06	3.528	0.040
MIXING×TIME	4.243E-06	4	1.061E-06	2.224	0.086
ERROR	1.717E-05	36	4.770E-07		

The ANOVA test were performed to find whether statistically significant differences were present between mixing groups. However, there was no significant difference on mixing groups and storage times.($p>0.05$)

Discussion:

Clinical treatment of edentulous patients with temporary soft lining materials have been done with an uncertainty of the effects the voids may bring, but as the results of our study, there was no noticeable difference in the viscoelasticity of Coe-Comfort® according to the three different mixing methods. The clinical consequences of mixing methods on the property of temporary soft lining materials were difficult to interpret from the limited results. All specimens of each mixing group showed almost no tendencies in extend of recovery over storage time. However, commonly at 3day measurement, there were a absolute reduction on thickness of all groups. It may be caused by time-dependant aging process and accumulated load effect, not by the effect of mixing methods. In order to find the changes in the initial 30 seconds we calculated the average linear regression of 10 specimens for each method of mixing, thus we conclude that there would be no harm in using any of these technique. Due to the accumulation effect, it is hard to record the elasticity of the material itself, if more than 30 seconds have passed since the masticatory load has put on.

Some edentulous patients who have the undesirable oral conditions such as alveolar bone loss, thin and relatively non-resilient mucosa, sharp alveolar bone, or severe undercuts, may not be completely satisfied with conventional dentures. In these situations, to relief discomfort, one of the most effective treatments is to use resilient denture liners. The temporary soft lining materials are multi-purpose products, it is caused by their ability to elastically recover following deformation during mastication over reasonable periods(Waters, 1996). It is for chair-side use and can be readily applied to an existing denture at impression surface in order to allow even force distribution, and promoting healing of tissue, or used as a temporary lining materials for interim prosthesis while post extraction resorption has occurred. But there are some limitation on the maintenance of their softness. This was probably due to the leaching out of the low molecular weight plasticizer, alcohol, and absorption of water which resulted in the dimensional change, high level of impurities, and deterioration in the vicoelasticity(Malström, 2002). Thus it exhibits time-dependant behavior during and following deformation. Theoretically, to resolve these problem , the corresponding slower leaching cycle has the beneficial effect of retarding the onset of polymer hardening, but the inevitable leaching can never be totally halted, only merely slowed. An obvious improvement would be to use a plasticizer which itself undergoes polymerization, and would not readily leach from the set polymer. But researching new materials is another problem to be continued, several clinical trials have been reported to find ideal controlling method, changing not only with the basic polymeric constituents, but also upon the time after mixing, the differential rate of penetration of the various liquids, the conditioning temperature, and the rate of liquid loss or of water uptake. However, the consequence is that the physical properties of any of these temporary soft lining materials are very variable. It means that the mechanism of set and property for the acrylic-based denture polymer is as yet uncertain in detail and no qualified utilities to define it. In addition, the properties which would be called ideal, for the clinical use has not been agreed upon and none to date perfectly meets it. For example, when used to condition abused tissue underlining ill-fitting dentures, the material should flow under a continuous weak pressure caused by tissue returning to their normal position, On the other hand, for temporary relining, the material should not flow out of the denture, to prevent the occlusal vertical dimension from changing after close adaptation to the tissue. But the general standardization of its property as a conditioner or an impression material is vague. Also through Sato's the finite element analysis of stress relaxation in soft denture liner, the more elastic (=low Young's modulus), the soft liner is more effective in the uniformalization of stress, however, if the soft denture liner has lower Young's modulus than the mucosa, stress concentrates adversely. Therefore, to obtain the optimum cushioning effect, the most elastic soft denture liner is not always the right choice.

Therefore, clinically it is important to obtain a good understanding of the manipulation of each material and to select a material suitable for each clinical purpose such as conditioning of abused tissues, functional impressions or temporary relining. This may sound as though clinical success and failure depends on the experience of the clinician. In this experiment, the meaning lies in the searching of the another option that can clinically change its property, while accepting the above limitations.

Ideally, it would be best to control the consistency depending on the purpose and be able to reproduce the same consistency with published results. When we consider the setting process of the Coe-Comfort®, it is a physical not chemical process. After the powder and liquid are mixed together to form a slurry, the ethyl alcohol initially swells the polymer beads, followed by solution in the dibutyl phthalate. The final matrix of the formed gel consists of dissolved polymer chain, alcohol, plasticizer, and undissolved powder. It is expected that during the process, the serial changes in the physical property will influence its consistency. For the above reason, in this study, we tried to find out about the influence of the mixing method such as machined mixing using impression material mixer, and vacuum treated mixing on its consistency. Many dwelled upon the negative effects of the voids that formed during mixing for the several reasons like those voids may harbor debris, bacteria, and oral yeasts that will further irritate tissue and it can create inaccuracies in the impression surface. Thus other studies have evaluated various mixing techniques intended to reduce the porosities that are incorporated into tissue conditioners and hence reduce void formation and microbial adherence. Utilizing a vacuum treatment during mixing procedure reduced the number of voids in the resultant material significantly. This does seem superficially attractive but Nimmo et al reported that microbial adherence was not affected by vacuum treatment(1985), which means that there is no difference in the microbial adherence between vacuum treated mixing and hand mixing. And no tests on the effect this would have on the mechanical properties of the material have been reported(Braden, 1995).

We hypothesized that if different mixing technique induce a change in its physical properties, we can selectively use different methods according to the state of the patient's mucosa and its clinical purpose. We designed the experiment based on that voids formed during mixing period may be beneficient for the cushioning effect it can supply as long as it dose not impede the surface integrity and that it can help in better controlling the consistency of the material.

Impression material mixer used in this study is worked by special vibrating and centrifugal mechanism and makes it possible to mix powder and liquid homogeneously. In the end, it provides a deeper and more rapid gelling period, and thus in practice a shorter setting time of the soft denture product. Its effect on working time and gelation time may determine the ease of manipulation after mixing and thickness(Murata, 1997). We anticipated that automatic mixing would induce faster penetration of alcohol to powder, and predicted that theoretically be more uniform and softer in the beginning. Also we predicted that by hand mixing, due to the void that were entrapped, the material can become physically more resilient like a air supplied matrix which have the capacity of energy absorbing. And it is possible to lose the resilient property more easily for the rupture or voids or increased contact surface to the environment. In the contrary, with vacuum treated mixing we expect the material to be more compact and elastic due to the elimination of voids. However, no valid difference was found in our vitro study. In order to find the changes in the initial 30seconds we calculated the average linear regression of ten specimens for each method of mixing., thus we conclude that there would be no harm in using any of these technique. If we estimate the elastic properties according to the extent of its restoration after being exerted with a dynamic load such as that from mastication, we can see from the result of this experiment that in all three methods, after three days of specimen preparing, the most displacement and the least restoration rate was recorded. On the other hand, three days before specimen preparing, although some elasticity would be seen accordingly as time passed, no similarities were found within each mixing technique. It can be interpreted that when the slope is steeper it is resilient, and when there is less deformation it is more elastic.

A laboratory study by Graham et al on the gelation and flow properties of soft liners indicated that initial flow is influenced by the time of loading, volume of the material, and applied load(Yoeli, 1996). Therefore this experiment, due to the inability of accurately replicating oral conditions and removing the influence of residual stress while measuring the differential result of dynamic load, failed to measure the effects on the initial physical properties of Coe-Comfort®. As a result, the experiment is more of a pilot study since the effects of air during mixing by static test should have been taken into consideration.

Another limitation of this study is that only one brand of tissue conditioner was used. The results therefore may not apply to other tissue conditioners.

Though it may be suggested that the effects of the prepared specimen's thickness on the result are the problem of this study because most published data and recommended techniques for applying soft liners show that a thickness of 2mm to 3mm is most appropriate(Graham, 1989) and Yoeli et al reported that thickness of tissue conditioners has a significant effect on measured softness: the thicker the tissue conditioner, the softer it is. However, according to Sato et al's finite element analysis of stress relaxation in soft denture liner, the thickness of soft denture liner had almost no effect on stress ration in their study(Sato, 2000). Kawana(1991) who examined the creep behavior and cushioning effect of soft lining materials, reported that a 1mm thickness of Coe-Comfort® is enough to distribute pressure uniformly over a short period of time. So, we can exclude the effect of the thickness of Coe-Comfort® affecting the results.

Since there are many factors affecting the temporary soft liner as previously mentioned, this experiment simplified the test conditions and simply differentiated the mixing techniques. Thus the results were relevantly meaningful to compare the mixing effect. Therefore it is not really necessary to take air into consideration while mixing process clinically but more precise Lab testing that attempts to simulate clinical conditions is necessary.

It is also apparent from the results of this study that the dental profession needs to develop specific performance properties for these materials. Additionally, future studies should be undertaken to evaluate how the physical/mechanical properties of soft denture liners relate to patient comfort and tissue health.

Conclusions:

This experiment measured the deformation rate of the temporary soft lining material under the dynamic load. The results of this study are summarized as follows.

1. Compared to the static load method, this method is thought to relatively deduct clinical result better.
2. There was no significant difference in the viscoelasticity depending on different mixing methods of the temporary soft lining material.
3. All specimens of each mixing group showed no noticeable tendencies in change of recovery over storage time.

More studies are needed in the future on analyzing the effects using the degree of void entrapment as a single factor and on the comparison of test design and various soft lining materials considering similar clinical conditions such as storage solution, storage temperature, and cycle and time of applying load.

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국문 요약

혼합법이 임시 연성 이장재인 Coe-Comfort®의 점탄성에 미치는 효과

류 현주

연세대학교 대학원 치의학과

지도교수 심 준성

조직 양화와 기능 인상 목적으로 널리 사용되는 임시 연성 이장재는 혼합시의 분말 액체 비율 뿐 아니라 혼합 후 함포(含泡) 정도에 따라 그 물성이 달라짐을 임상에서 관찰할 수 있으며, 이는 재료의 점탄성 뿐 아니라 연성의 유지 기간에도 영향을 미치게 된다. 본 연구에서는 수동 혼합, 인상재 혼합기를 이용한 기계 혼합, 진공 처리 혼합과 같이 함포 정도에 영향을 줄 수 있는 서로 다른 방법으로 임시 연성 이장재인 Coe-Comfort®(Coe Lab., Illinois, USA)를 혼합하여 시편을 제작하고, 이를 저작 주기를 고려한 동적 하중에 노출 시켰을 때 시편 두께의 변이를 측정, 비교하여 혼합법에 따른 동적 하중에 대한 변형 양상을 비교 하고자 하였다.

각각의 혼합법 당 10개의 시편을 준비하여 증류수에 보관하면서, 혼합 후 연속적으로 2시간, 12시간, 1일, 2일, 3일 되는 시점에 2Hz로 1분간 동적 하중을 가하며 실시간으로 두께 변화를 측정하고, 기록된 초기 30초간의 측정값을 선형 회귀 분석 후 그 기울기를 혼합법과 저장 시간에 따른 이원 분산 분석법으로 통계 처리하였다.

분석 결과 모든 측정 시점에서 혼합 방법에 따른 변형 양상의 차이는 관찰되지 않았고($p>0.05$) 세 군 모두에서 저장시간의 증가와 하중에 대한 변형 사이에는 유의할 만한 차이가 없었다($p>0.05$). 본 연구 결과는 저장 용액이 증류수인 점과 하중에 노출되는 시간이 짧았던 점 등의 제한을 가지나, Coe-Comfort®의 동

적 하중에 대한 두께 변이 정도는 분말 용액 비가 일정하다면 혼합법에 유의할 만한 영향을 받지 않음을 의미하며, 향후 함포 정도를 단일 요소로 한 효과 분석 실험과 저장 용액, 저장 온도, 하중 부여 주기와 시간 등을 임상조건과 유사하게 고려하는 실험 설계 및 다양한 연성 이장재에 대한 비교 실험이 필요할 것으로 사료된다.

핵심 되는 말 : 임시 연성 이장재, 혼합법, 동적 하중, 점탄성