An alcohol-free tissue conditioner – a laboratory evaluation

H. Murata[a,*], Y. Narasaki[a], T. Hamada[a], J. F. McCabe[b]

[a]Department of Prosthetic Dentistry, Graduate School of Biomedical Sciences, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima, 734-8553, Japan
[b]Dental Materials Science Unit, The Dental School, University of Newcastle upon Tyne, Framlington Place, Newcastle upon Tyne, NE2 4BW, UK

*Corresponding author: Dr Hiroshi Murata, Department of Prosthetic Dentistry, Graduate School of Biomedical Sciences, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima, 734-8553, Japan. Tel.: +81-82-257-5681; fax: +81-82-257-5684.
E-mail address: hmurata@hiroshima-u.ac.jp

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Short title: An alcohol-free tissue conditioner

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Summary *Objectives.* An alcohol-free tissue conditioner based on a n-butyl methacrylate / i-butyl methacrylate copolymer has recently been developed. The purpose of the present study was to compare some key properties of the new tissue conditioner with those of poly (ethyl methacrylate) – based conventional materials containing ethyl alcohol. The effect of a coating, which consisted of poly (ethyl methacrylate) and methyl methacrylate, was also evaluated.

Methods. The new alcohol-free tissue conditioner (Fictioner) and 3 tissue conditioners containing ethyl alcohol (FITT, Hydro-Cast, SR-Ivoseal) were evaluated. The coated alcohol-free material was also used. Gelation characteristics, dynamic viscoelastic properties and compatibility with dental stones were measured using a displacement rheometer, dynamic viscoelastometer and profilometer, respectively. In addition, weight changes during immersion in water were determined.

Results. The working time and gelation time of the alcohol-free tissue conditioner were similar to those of the conventional materials. This alcohol-free material had significantly lower shear storage modulus and shear loss modulus, and higher loss tangent ($P < 0.05$) than FITT and SR-Ivoseal at 0.01 and 1 Hz. The alcohol-free material maintained its inherent viscoelastic properties and exhibited only a slight change in weight during 14 days of water immersion when compared to the conventional materials. The application of the coating significantly reduced the loss of the initial viscoelastic properties and surface quality during the test periods.

Conclusions. The coated alcohol-free tissue conditioner would be superior to the conventional materials containing ethyl alcohol in view of viscoelastic properties after gelation, compatibility with dental stones and durability.

Introduction

The application of a tissue conditioner having viscoelastic properties has been found to be effective in partial and complete denture patients for reconditioning of denture-bearing mucosa inflamed and distorted by ill-fitting dentures and making it possible to record functional impressions, provide aftercare of an immediate denture and in implant therapy.[1-3] They are supplied as powder and liquid components for chair-side use. The main component of the polymer powder of the conventional materials is poly (ethyl methacrylate) or a related copolymer.[4] The liquid is a mixture of an ester-based plasticizer, such as butyl phthalyl butyl glycolate, dibutyl phthalate and dibutyl sebacate, and ethyl alcohol (EtOH).[5] The nature of the materials may alter considerably from one product to another due to differences in plasticizer type,[5-7] EtOH content in the liquids,[5-7] molecular weight[4,7] and particle size[8] of the poly (ethyl methacrylate) powders, and the powder / liquid (P/L) ratio.[2,7,9] However, essentially, the fundamental composition has remained unchanged since their introduction.[10]

When the powder and liquid are mixed together, polymer chain entanglements occur, resulting in formation of a physical gel.[11] Although the ester-based plasticizers are good solvents for poly (ethyl methacrylate), the gelation speed would be very slow because the large plasticizer molecules alone penetrate the poly (ethyl methacrylate) particles very slowly. That is, the tissue conditioners based on poly (ethyl methacrylate) containing no EtOH do not show a clinically acceptable gelation time and these materials are not suitable for clinical applications. Therefore, EtOH is an essential additive for the poly (ethyl methacrylate) - based system to produce the clinically acceptable gelation time because the penetration of the plasticizer into the polymer and the resulting chain entanglements are greatly accelerated by the presence of EtOH.[7]

An ideal tissue conditioner would maintain the initial viscoelastic properties and surface integrity over relatively long time periods in order to treat abused and distorted tissues efficaciously and make accurate functional impressions.[2,3] However, most of the commercially available materials suffer loss of viscoelastic properties and increase in the surface roughness with time due to the process of leaching of EtOH into the oral environment and water absorption into the materials.[2,5,12,13] It has been reported that EtOH is lost within 24 hours from the materials, whereas the loss of ester plasticizer ranges from 0.03 mg/g to 8.70 mg/g within 14 days.[5] The amount of leaching of EtOH is considerably larger than that of the ester plasticizer. Furthermore, the taste and sensation of EtOH are objectionable to many patients.[1,14] For this reason, a coating material is used to extend the life of the tissue conditioner sometimes.[3,15] This material is applied to the surface of the lining once it has gelled, with a brush. However, it is also

necessary to improve the tissue conditioner itself. Some studies have been reported on the properties of tissue conditioners containing no EtOH based on poly (butyl methacrylate)[16] and n-butyl methacrylate / ethyl methacrylate copolymers.[11,17] These studies have provided useful information on the development of a new type of tissue conditioner.

An alcohol-free tissue conditioner based on a n-butyl methacrylate / i-butyl methacrylate copolymer has recently been developed by the authors in order to overcome the above-mentioned disadvantages of the poly (ethyl methacrylate) - based conventional tissue conditioners containing EtOH. This material is the first alcohol-free tissue conditioner to be used in clinical situations. The purpose of the present study was to evaluate some key properties of the new tissue conditioner in comparison to the conventional materials and also the effect of a coating for the material. It was hypothesized that the alcohol-free tissue conditioner would be superior in maintaining initial properties compared to the conventional materials.

Materials and methods

Table 1 lists the 4 tissue conditioners used in this investigation together with manufacturer, composition of powder[4] and liquid,[5] and powder/liquid (P/L) ratio recommended by manufacturers. The new product is Fictioner, co-developed by the authors and Nissin Dental Products Inc, Japan, which does not contain ethyl alcohol (EtOH) in the liquids. The major component of the powder is 90/10 n-butyl methacrylate / i-butyl methacrylate copolymer along with a small amount of poly (ethyl methacrylate). The surfaces of the n-butyl methacrylate / i-butyl methacrylate copolymers are coated with silicon dioxide. The liquid consists of only plasticizers (dibutyl sebacate and butyl phthalyl butyl glycolate). This product is also packaged with Top Coat, a coating which is a mixture of poly (ethyl methacrylate) and methyl methacrylate. The other 3 test products are poly (ethyl methacrylate) - based systems contained 12 to 48 wt% EtOH. Fictioner samples coated with Top Coat (batch no. BID-L) were also measured to evaluate the effect of the coating on some properties over a 14-day period.

Working time and gelation time

Working time and gelation time were determined using a displacement rheometer. Details of this device have been reported.[18] This device, which measures clinically relevant changes in the elastic recovery of the setting materials, was suited for the determination of the working time and gelation time of tissue conditioners.[19] After mixing the powders and liquids according to the manufacturers' instructions at 23 °C,

the resulting paste was placed in the rheometer and 0.25 mm displacements were made at intervals of 30 seconds. Five tests were carried out both at 23 °C (working time) and at 37 °C (gelation time) for each material.

The working time was defined as the time (from start of mixing) when initial elastic recovery of the material was observed at 23 °C. The gelation time was when the material reached a maximum elastic recovery at 37 °C.

Dynamic viscoelastic properties

Dynamic viscoelastic properties were determined using an automatic dynamic viscoelastometer (Rheovibron DDV-25FP, Orientec Corp., Tokyo, Japan) based on a non-resonance-forced vibration principle. This device measures the response of a material to a sinusoidal or other periodic stress. Five pairs of specimens of each material were prepared to 2 mm thickness (30mm long X 20mm wide) according to the manufacturers' instructions. These specimens were stored in distilled water at 37 °C. A series of dynamic mechanical tests was conducted at 37 °C on pairs of specimens with the use of a shearing jig 2 hours after mixing (no immersion in water; baseline), after 24 hours, 3 days, 7 days, and 14 days. The complex dynamic shear modulus (G^*), shear storage modulus (G'), shear loss modulus (G''), and loss tangent (tan δ) were determined over a frequency range of 0.01 to 100 Hz (at 37 frequency measuring points) with a 0.7 % strain.

G^*, G', G'', and tan δ are defined as:[20]

$G^* = G' + iG''$

$G' = |G^*| \cos \delta$

$G'' = |G^*| \sin \delta$

$\tan \delta = G''/G'$

where $i = \sqrt{-1}$, and δ = phase angle between stress and strain. G^* is resolved into two components - G', which represents the elastic component of material behaviour, and G'', which represents the viscous component of material behaviour. Tan δ is a measure of the amount of energy absorbed by the material during cyclic deformation, and gives an indication of the relative contributions of the elastic and viscous components of the material behaviour.

Weight changes

Five specimens of each material were made into disks 2 mm in thickness and 30 mm in diameter using a Teflon mould and flat glass plate. The specimens were weighed to an accuracy of 0.0001 g at 2 hours after mixing, and stored in distilled water at 37 °C. They were removed, blotted dry and reweighed at the same time as the dynamic mechanical tests, *i.e.*, at 24 hours, 3 days, 7 days, and 14 days after specimen preparation. The

weight change of the tissue conditioners was expressed as a percentage using the following formula:[13]

Weight change (%) = $(W - W_1) \times 100 / W_1$

where W = the weight of the tissue conditioner, and W_1 = initial weight of the tissue conditioner before immersion in water (2 hours after mixing).

Compatibility with dental stones

A type 4 dental stone (Die Stone, Batch No. 0011156; Heraeus Kulzer, South Bend, Ind, USA) was used. After mixing powder and liquid of the tissue conditioner at 23 °C, the mixture was poured into a container of inner diameter 18 mm and depth of 2 mm. A flat glass plate (mean surface roughness value: 0.008 μm) was then centred above the container. The glass plate was removed from the tissue conditioner 2 hours after mixing, and the specimens were stored in distilled water at 37 °C. Fifteen specimens were prepared for each tissue conditioner. The 3 specimens were removed from the water bath at the same time of immersion in water as the dynamic mechanical tests and test for weight changes, respectively. The powder of dental stone and water were mixed mechanically and under vacuum in a water / powder ratio recommended by the manufacturer. Mixed plaster was then poured over the impression surface of the tissue conditioners. The dental stone cast was removed from the tissue conditioners 60 minutes after pouring.

Mean surface roughness (R_a) values of the dental stone casts made from the tissue conditioners were determined using a profilometer (length of tracing = 2.5 mm, cut-off value = 0.8 mm)[21] (Surfcorder SE-3000, Kosaka Laboratory Ltd., Tokyo, Japan). Five measurements for each specimen, *i.e.*, fifteen measurements for each tissue conditioner at certain time of immersion, were performed.

Statistical analysis

Comparisons of working time and gelation time were subjected to a one-way Analysis of Variance (ANOVA) combined with a Student-Newman-Keuls test at a 5 % level of significance. Two-way ANOVAs were performed to find whether statistically significant differences were present between materials and immersion times for the rheological parameters, *i.e.*, G', G'' and tan δ, % weight change and R_a. Two frequencies of 0.01 and 1 Hz were selected for statistical analyses. The differences among materials and those among immersion times were tested with a Student-Newman-Keuls test at a 5 % level of significance. T-test was also used to determine whether statistically significant differences exist between G' and G'' for 0.01 and 1 Hz.

Results

The working times and gelation times of the 4 tissue conditioners are shown in Figs. 1 and 2, respectively. A wide range of gelation characteristics was found among the tissue conditioners tested. Hydro-Cast had a significantly longer working time ($P < 0.05$) than the other 3 materials. No significant difference was found between the working times of Fictioner and SR-Ivoseal, which had significantly longer working times ($P < 0.05$) than FITT. Hydro-Cast also had a significantly longer gelation time ($P < 0.05$) than Fictioner, FITT and SR-Ivoseal. No significant differences were found among the gelation times of these 3 materials.

All tissue conditioners exhibited higher values of storage modulus (G') and loss modulus (G'') at higher frequencies. Loss tangent (tan δ) of Fictioner, FITT and SR-Ivoseal decreased as the frequency increased from 0.01 to approximately 1 Hz, then increased again at higher frequencies. Tan δ of Hydro-Cast went through a minimum at approximately 10 Hz. G', G'' and tan δ of the 5 materials at 0.01 and 1 Hz 2 hours after mixing are shown in Fig. 3. Values of G' were significantly higher ($P < 0.05$) than G'' at 0.01 and especially 1 Hz for all materials except for Hydro-Cast at 0.01 Hz. At both frequencies, FITT had the highest G'. Values of G' of Fictioner, coated Fictioner and Hydro-Cast were significantly lower ($P < 0.05$) than those of the other 2 materials. No significant differences were found among G' of these three materials. Almost similar results were obtained for the values of G''. Hydro-Cast had the highest tan δ at both frequencies. The order of tan δ values were Hydro-Cast > Fictioner coated with Top Coat > Fictioner > FITT, SR-Ivoseal.

Variations of G', G'' and tan δ with time of immersion for the 5 materials at 1 Hz are shown in Fig. 4. The ANOVA results indicate significant differences among the materials and significant effects of immersion time for these rheological parameters ($P < 0.05$). G' and G'' of FITT increased most significantly with time ($P < 0.05$). Those of SR-Ivoseal increased rapidly until 24 hours of water immersion, and decreased from 24 hours to 14 days. Fictioner and Hydro-Cast showed a significant increase in G' and G'' ($P < 0.05$), however, the increase rate of these values of Fictioner with time was lower than that of Hydro-Cast. Changes in G' and G'' on immersion for 14 days were insignificant for Fictioner coated with Top Coat (G': $P = 0.251$; G'': $P = 0.692$). Tan δ of FITT and SR-Ivoseal increased significantly with time ($P < 0.05$), whilst that of Fictioner, coated Fictioner and Hydro-Cast decreased significantly with time ($P < 0.05$). Changes in tan δ for Fictioner and coated Fictioner were smaller than those for the other 3 materials.

Weight changes with time for the 5 materials are indicated in Fig. 5. The ANOVA results indicate significant differences among the materials and significant effects of

time of immersion for the percentage changes in weight ($P < 0.05$). Coated Fictioner, FITT and Hydro-Cast showed a decrease in weight during water immersion. The rapid weight loss was recorded until 24 hours of water immersion for these materials, and there was a gradual change in weight from 24 hours to 14 days. The greatest weight loss was observed in Hydro-Cast, and the least weight loss was in Coated Fictioner. SR-Ivoseal also showed a decrease in weight until 24 hours of immersion. However, the weight of this material increased rapidly and greatly from 24 hours to 14 days of immersion. Fictioner exhibited a slight increase in weight during water immersion.

Variations of surface roughness (R_a) values of dental stone casts made from the 5 materials with time of immersion are shown in Fig. 6. The ANOVA results indicate significant differences among some of the materials and significant effects of time of immersion for the R_a values of the dental stone casts ($P < 0.05$). However, no significant differences were found among the R_a values of the stone casts made from Fictioner, coated Fictioner, FITT and Hydro-Cast 2 hours after mixing, *i.e.*, before immersion in water. Furthermore, the dental stone casts made from these 4 materials showed significantly lower R_a values ($P < 0.05$) as compared to those made from SR-Ivoseal. All tissue conditioners showed statistically significant increases in R_a values with time ($P < 0.05$). However, the change following immersion for 14 days was very slight for coated Fictioner, and there were no statistically significant differences among those values after 2 hours, 24 hours and 3 days. In addition, dental stone casts made from coated Fictioner were smoother than those made from the other materials during 14 days of water immersion, while the R_a values of SR-Ivoseal were the highest among all of the tested materials.

Discussion

The hypothesis that the alcohol-free tissue conditioner based on a n-butyl methacrylate / i-butyl methacrylate copolymer would be superior to the poly (ethyl methacrylate) - based conventional materials containing ethyl alcohol (EtOH) in view of maintaining inherent viscoelastic properties during immersion in water was accepted. However, it was found that the coating was essential for maintaining the surface integrity of the alcohol-free tissue conditioner because the surface roughness of the uncoated material increased with time of immersion.

The alcohol-free tissue conditioner (Fictioner) has been developed in order to solve the problem of the conventional tissue conditioners containing EtOH, such as loss of softness of the materials and deterioration in surface condition with the passage of time, and patient complaints caused by the bitter taste of EtOH. The determination of major

component of polymer powders was one of the most important factors in development of this material. N-butyl methacrylate / i-butyl methacrylate copolymer along with a small amount of poly (ethyl methacrylate) was used as the powder component. Generally, a polymer dissolves in certain solvents having the same solubility parameter (defined as the square root of the cohesive energy density) as the polymer.[6,7] Thus, the solubility parameters of the powders and liquids of tissue conditioners should be equal. Furthermore, glass transition temperature (T_g) of the polymers should be higher than the room temperature to prevent fine particles from coalescing.[11] The powder of the conventional tissue conditioners consists of poly (ethyl methacrylate) because the solubility parameter of poly (ethyl methacrylate) is well met by EtOH and ester-based plasticizers, and T_g of this polymer is higher than the room temperature.[11] The poly (ethyl methacrylate) - based system needs EtOH in the liquid component to achieve the adequate gelation speeds. Poly (n-butyl methacrylate) and related copolymers have solubility parameters which are within the range of those of plasticizers, and diffusion of plasticizers into these polymers would be more rapid than in poly (ethyl methacrylate) due to enhanced polymer chain mobility.[11] For these reasons, the material based on n-butyl methacrylate / i-butyl methacrylate copolymer will produce a faster gelation time than that based on poly (ethyl methacrylate) without EtOH in the liquids. However, this copolymer has a T_g near or below room temperature, resulting in the agglomerate during storage. Coating of the surfaces of n-butyl methacrylate / i-butyl methacrylate copolymers by silicon dioxide enabled the storage in powder form for a long time. Fictioner contains a small amount of poly (ethyl methacrylate) to adjust the gelation time because the powders consisted of only n-butyl methacrylate / i-butyl methacrylate copolymers produce too fast gelation speed for clinical applications. The incorporation of poly (ethyl methacrylate) into the n-butyl methacrylate / i-butyl methacrylate copolymers would reduce the gelation times, which leads to clinically adequate manipulation after mixing. Furthermore, the coating material (Top Coat) has been also developed to prevent water absorption into Fictioner because water absorption into the material causes the limit of the intra-oral life of the material.

The alcohol-free tissue conditioner (Fictioner) had a gelation characteristic very similar to SR-Ivoseal. The gelation speeds of these two materials were between those of Hydro-Cast and FITT. Hydro-Cast demonstrated the longest working time and gelation time. The efficacy in the clinical use of tissue conditioners is considered to be influenced by their thickness as well as the viscoelastic properties and compatibility with dental stones. To be effective, a 2-mm thickness of tissue conditioner is recommended.[9] Hydro-Cast which showed slower gelation speed may be more difficult

to manipulate after mixing in order to produce the optimum thickness in the mouth compared with the other 3 materials. Thus, the placement of the denture containing Hydro-Cast in the mouth should be delayed until the flow lessens or the patients' closing force should be carefully controlled in order to produce a sufficient thickness of the conditioning layer. Conversely, Fictioner, SR-Ivoseal and FITT would be easier to manipulate and apply to dentures at the optimum thickness because they developed elastic recovery gradually, shortly after being mixed. The denture lined with these materials may be removed from the mouth for trimming a short time after the placement of the denture in the mouth.

The dynamic viscoelastic behaviour of all the tissue conditioners was sensitive to changes in frequency. However, large differences in rheological parameters were found among the materials. The viscoelastic characteristics at 1 Hz and lower frequencies would simulate behaviour under typical masticatory conditions and under exposure to a continuous weak pressure caused by mucosal tissues returning to their normal positions, respectively. In particular, loss tangent (tan δ) values (loss modulus (G'') / storage modulus (G')) from 0.01 to 1 Hz are considered to be important for clinical assessment of the results of dynamic mechanical tests. The higher values of tan δ at 1 Hz and lower frequencies would reflect a greater cushioning effect on masticatory forces and higher efficacy in reconditioning of abused tissues, respectively.[22] Therefore, two specific frequency points (0.01 and 1 Hz) were selected for evaluation. The alcohol-free tissue conditioner (Fictioner) (having higher tan δ both at 0.01 and 1 Hz than FITT and SR-Ivoseal) had a large flow, which would allow the abused denture-bearing mucosa to recover to a healthy state and record the shape of the mucosa under functional stress more effectively. Before immersion in water, Hydro-Cast gave an even greater flow than Fictioner. However, Fictioner showed the lower rate of change of flow with the passage of time. This material exhibited only a 5 % decrease of tan δ at 1 Hz after 24 hours of water immersion as compared to the value of the material before immersion, and then remained almost unchanged from 24 hours to 14 days of water immersion. This behaviour may be attributed to almost no leaching out of the liquid components into the water because Fictioner contains no EtOH. On the other hand, the tissue conditioners with the higher EtOH content tended to exhibit the larger changes in tan δ at 1 Hz (approximately –30 to 112 %) and deteriorate during immersion in water probably due to a loss of EtOH.[5] Similar tendencies were observed for the other rheological parameters. These results suggest that the alcohol-free tissue conditioner (Fictioner) continues to have larger flow property over relatively long time periods. Furthermore, Fictioner coated with Top Coat exhibited larger flow property, perhaps because the

methyl methacrylate monomer included in the coating might diffuse into the tissue conditioner. The coated Fictioner retained the softness longer than uncoated Fictioner during immersion.

Tissue conditioners undergo two processes when immersed in water: plasticizers and especially EtOH are leached out into the water and, at the same time, water is absorbed by the materials. FITT and Hydro-Cast lost weight during immersion in water (maximum –4.1 % and –9.0 %, respectively) because the percentage solubility of EtOH and plasticizers would be higher than the percentage absorption of water. For SR-Ivoseal, there was a considerably large weight gain (maximum 21.8 %); this may be ascribed to the higher percentage absorption of water than the percentage solubility. Fictioner underwent a slight weight gain during 14 days of water immersion (maximum 1.9 %) probably due to the absorption of water and no loss of EtOH. Conversely, coated Fictioner underwent a slight weight loss during immersion (maximum –1.8 %). This small weight loss would have been caused by the leaching of the methyl methacrylate monomer from the coating. It appears that the coating prevent absorption of water. This view is consistent with the previous reports on the effect of coatings of tissue conditioners.[3,15]

The compatibility with dental stones is one of the important factors used to assess tissue conditioners as functional impression materials. Fictioner coated with Top Coat (1.14 to 1.74 μm) produced smoother surfaces on the dental stone than the other 3 materials (FITT: 1.29 to 3.40 μm; Hydro-Cast: 1.40 to 5.22 μm; SR-Ivoseal: 6.09 to 15.19 μm) and uncoated Fictioner (1.85 to 5.11 μm) during 14 days of water immersion, and showed minimal changes in surface roughness over time. This suggests that the prevention of water absorption by application of the coating is effective in producing and maintaining a smoother surface quality.

The results suggest that the coated alcohol-free tissue conditioner (Fictioner) would be superior to the conventional tissue conditioners containing EtOH from the point of view of dynamic viscoelastic properties after gelation, compatibility with dental stones and their durability. Clinically, the authors have observed that Fictioner is sticky, resulting in adhesion of some food debris to the surface. This material is somewhat more difficult to mix immediately after the powder is added to the liquid than the poly (ethyl methacrylate) - based conventional materials. This phenomenon has not been detected by the rheometer used in the present study. We also have observed that some patients complain of the irritancy of methyl methacrylate included in the coating (Top Coat) just after being applied. Further research is needed to develop improved materials which have the advantages of Fictioner and Top Coat but that do not have these deficiencies.

Conclusions

1. The alcohol-free tissue conditioner based on a n-butyl methacrylate / i-butyl methacrylate copolymer had a clinically acceptable working time and gelation time.
2. The alcohol-free tissue conditioner had relatively large flow properties and most stable durability over relatively long time periods compared to the tissue conditioners containing ethyl alcohol.
3. The inherent viscoelastic properties and surface integrity of the alcohol-free tissue conditioner were maintained longer when the coating was applied.
4. From the standpoint of dynamic viscoelastic properties, compatibility with dental stones and their durability, the coated alcohol-free tissue conditioner would have a greater ability to condition abused tissue and make functional impressions than the tissue conditioners containing ethyl alcohol.

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Table 1 Materials used in the study

Material	Manufacturer	Composition			P/L by weight	Batch no. powder/liquid
		Powder	Liquid			
			Plasticizer	EtOH (wt%)		
Fictioner	Nissin Dental Products Inc., Kyoto, Japan	Poly (n-butyl methacrylate / i-butyl methacrylate) Poly (ethyl methacrylate)	Dibutyl sebacate Butyl phthalyl butyl glycolate	0	2.0	BLH-L BIC-L
FITT	Kerr Mfg. Co., Romulus, USA	Poly (ethyl methacrylate) Poly (methyl methacrylate)	Dibutyl phthalate	19.6	2.0	1-1159 1-2333
Hydro-Cast	Kay-See Dental Mfg. Co., Kansas City, USA	Poly (ethyl methacrylate)	Butyl benzyl phthalate	12.4	0.9	1410010461 1460010466
SR-Ivoseal	Ivoclar AG, Schaan, Liechtenstein	Poly (ethyl methacrylate) Poly (methyl methacrylate)	Dibutyl sebacate	48.1	1.5	B14124 A25615

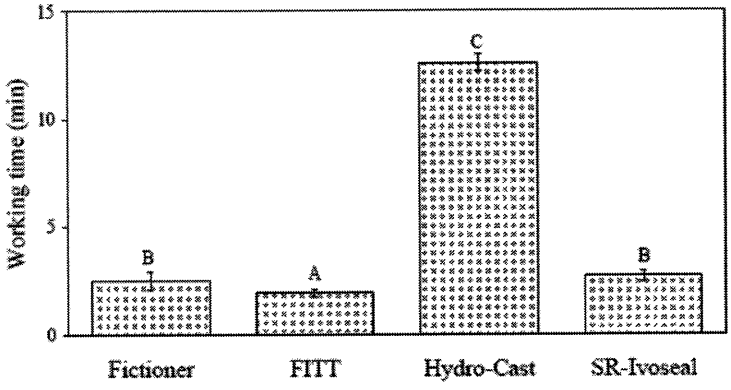

Figure 1 Working times of 4 tissue conditioners with standard deviation bars. Identical letters indicate no statistical differences.

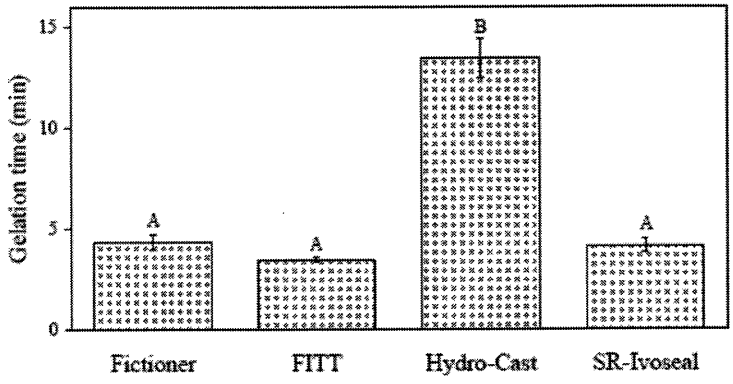

Figure 2 Gelation times of 4 tissue conditioners with standard deviation bars. Identical letters indicate no statistical differences.

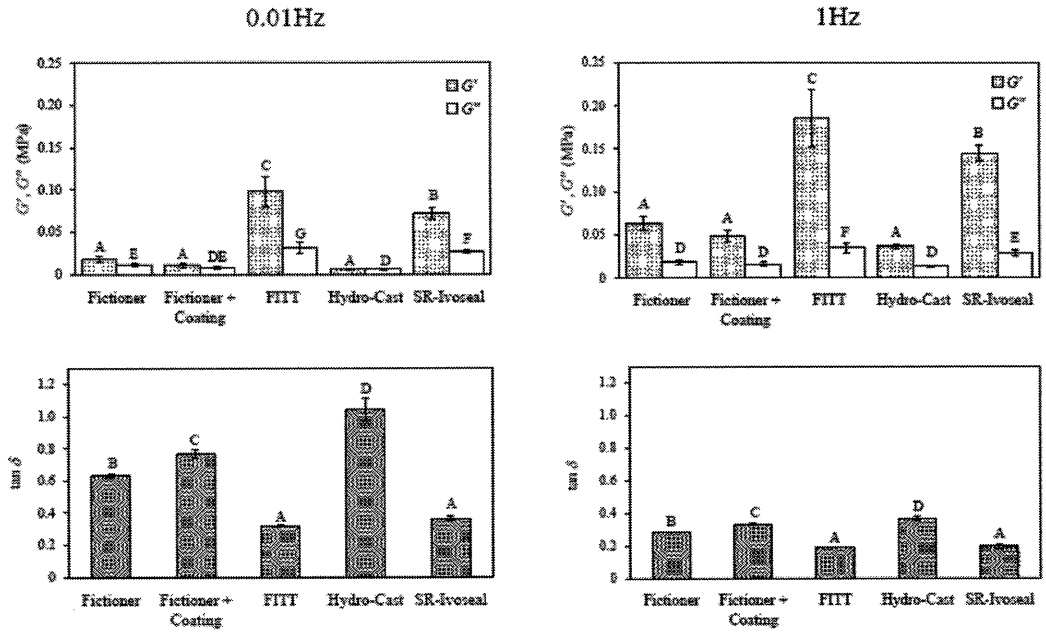

Figure 3 Storage modulus (G'), loss modulus (G'') and loss tangent (tan δ) of 4 tissue conditioners and 1 coated tissue conditioner at 0.01 and 1 Hz 2 hours after mixing. Identical letters indicate no statistical differences.

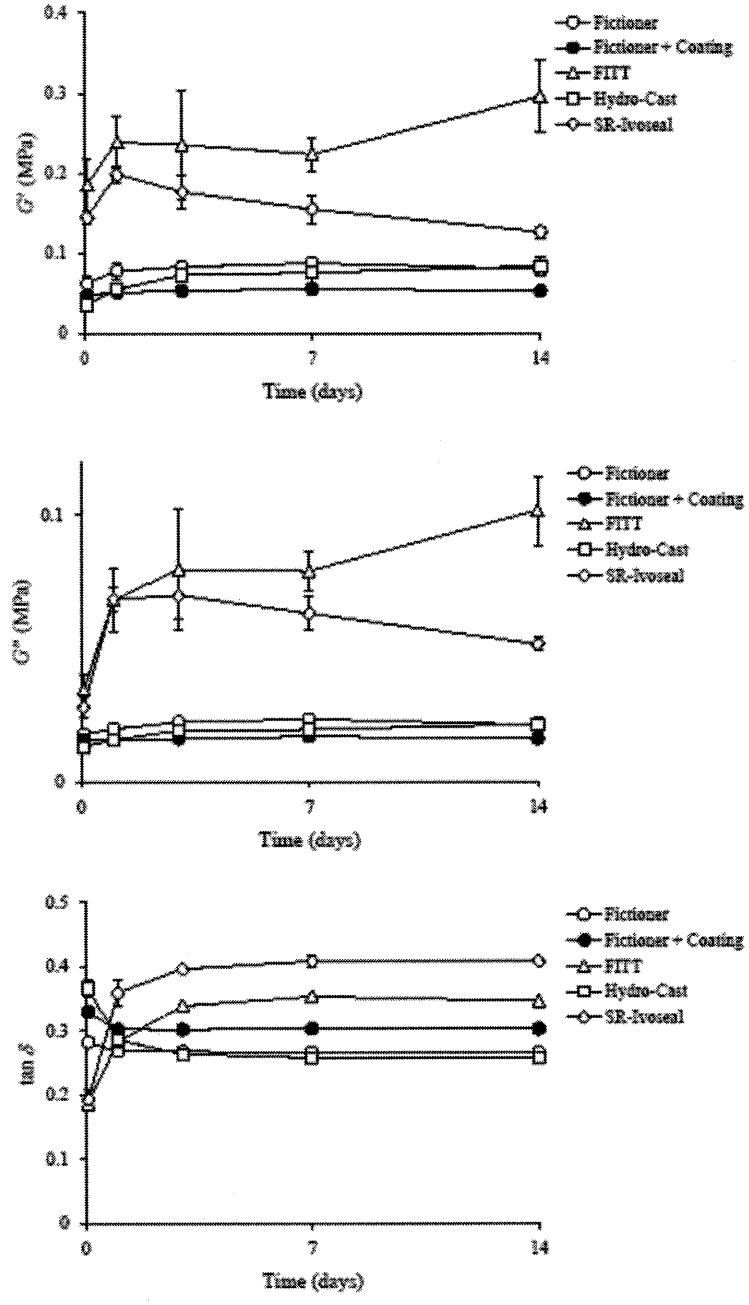

Figure 4 Variations of storage modulus (G'), loss modulus (G'') and loss tangent (tan $\delta$with time of immersion in water for 4 tissue conditioners and 1 coated tissue conditioner at 1 Hz. Error bars indicate standard deviation.

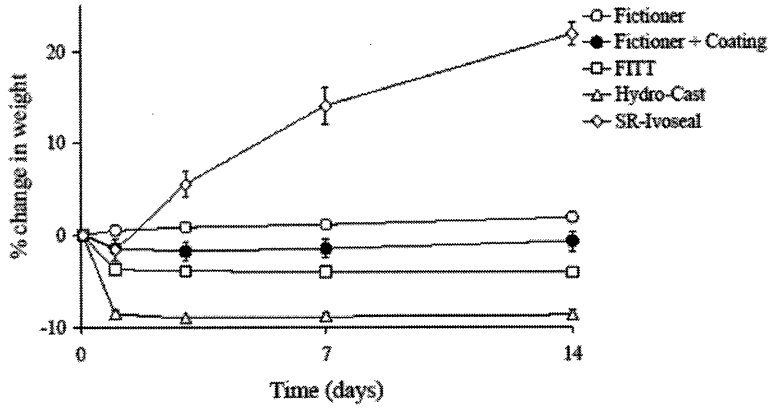

Figure 5 Percentage changes in weight with time for 4 tissue conditioners and 1 coated tissue conditioner in water immersion. Error bars indicate standard deviation.

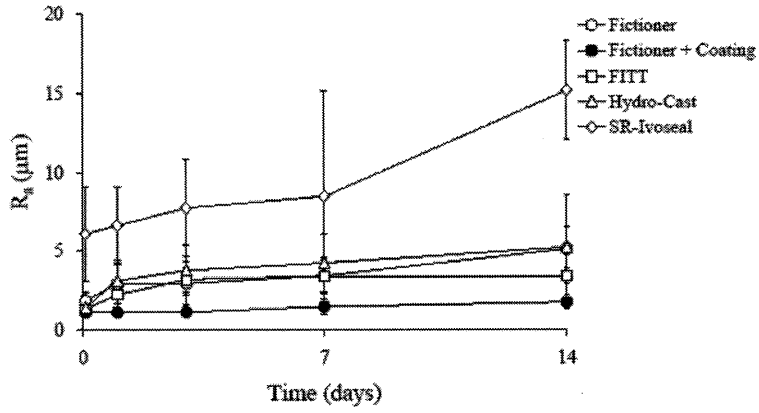

Figure 6 Variations of surface roughness (R_a) values of dental stone casts made from 4 tissue conditioners and 1 coated tissue conditioner with time of immersion in water. Error bars indicate standard deviation.