Compatibility of tissue conditioners and dental stones: effect on surface roughness

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ABSTRACT

Statement of problem. Although the primary use of tissue conditioners is to treat abused mucosa, these materials are also frequently used as functional impression materials. There is no information on the effect that these materials may have on the surface of the resultant dental stone cast.

Purpose. This study evaluated the compatibility of 3 tissue conditioners with dental stones and changes in surface conditions over time.

Material and methods. Three tissue conditioners (COE-comfort, Soft-conditioner, Visco-gel) and 4 dental stones (Capstone DF, New Plastone, Die Stone, New Fujirock) were evaluated. One elastomeric impression material (Examixfine) was used as a control. Tissue conditioner disks were made by pouring freshly mixed material into a polypropylene container, pressing it down with a glass plate, and then removing the plate 2 hours later. The disks were then stored in distilled water for 0 or 24 hours, or 3, 7 or 14 days. Subsequently, each dental stone was mixed and poured over the top of each disk, and allowed to remain for 60 minutes. Twenty-five disk-shaped specimens, 18 × 2 mm, for each tissue conditioner/stone cast combination were prepared. Mean surface roughness (R_a) values of the dental stone casts made from the tissue conditioners were determined using a profilometer. Five measurements for each specimen were made. Data were analyzed with 1- and 3-way ANOVA and the Student-Newman-Keuls test (α=.05). Detail reproduction was also determined using a ruled test block, as specified in ISO specification 4823.

Results. Contribution ratios determined by 3-way ANOVA indicated that the surface roughness values were significantly more influenced by the time of immersion in water (P<.0005, contribution ratio ρ=37%), than the type of tissue conditioner (P<.0005, ρ=19%) or dental stone used (P<.0005, ρ=1%). The best surface quality was obtained with a New Fujirock cast (0.81 $\pm$ 0.06 μm), followed by New Plastone (0.83 $\pm$ 0.12 μm) and Die Stone (0.85 $\pm$ 0.05μm) casts, in combination with Visco-gel without immersion in water, and those were nearly equivalent in surface roughness to a Die stone cast from Examixfine. The surface roughness values of all specimens, especially the COE-comfort/stone cast combinations, significantly increased with tissue conditioner immersion time (P<.0005). Visco-gel tended to produce a better surface quality during the test periods than the other materials. All stone casts made from the tissue conditioners not immersed in water reproduced 20 μm or 50 μm-lines, while the detail diminished over time with immersion.

Conclusion. The type of tissue conditioner and especially immersion time has a significant effect on the surface quality of dental stone casts. The type of dental stone

used is less important.

Clinical implications

This in vitro study suggests that the suitable period for making functional impressions from tissue conditioners ranges from 24 hours to 3 days after applying the resilient liner, and quality is dependent upon the type of tissue conditioner used. The type of dental stone used is less important.

INTRODUCTION

Tissue conditioners are used for the conditioning of denture-bearing mucosa abused by ill-fitting dentures prior to fabricating new dentures, relining existing dentures, and for provisional relining of immediate dentures and ill-fitting dentures.[1-3] They have also been used as functional impression materials to yield accurate impressions of the oral structure.[1-4] Their efficacy as functional impression materials is influenced by rheological properties,[5,6] dimensional stability,[4,7,8] ability to reproduce details[4,7] and undercuts,[9] and durability.[6] Furthermore, the compatibility of these materials with dental stones is an important.[4,7]

Tissue conditioners are generally supplied as a separate powder and liquid, which are mixed and applied to the denture clinically. The powder generally consists of poly (ethyl methacrylate) or a related copolymer,[10] while the liquid is an ester plasticizer, such as dibutyl phthalate, butyl phthalyl butyl glycolate, butyl benzyl phthalate or dibutyl sebacate, and 4 wt% to 50 wt% ethyl alcohol.[11] The powder component contains no initiator and the liquid no monomer,[11] thus mixing the 2 results in the dissolution of polymers into a solvent, followed by polymer chain entanglement and formation of a gel.[12] Initially, the materials exhibit viscoelastic behavior suitable for tissue conditioning and functional impression making. However, it has been reported that tissue conditioners undergo a marked loss of initial viscoelastic properties,[5,6,13,14] dimensional changes,[4,7,8] and diminution of detail reproduction[7,15] over time due to the leaching out of the plasticizer and ethyl alcohol components[11,16] as well as from absorption of water into the materials.[8]

Many studies have reported the compatibility of irreversible hydrocolloid and elastomeric impressions with dental stones.[17-20] To assess the physical properties of tissue conditioners used as functional impression materials, it is also necessary to determine the changes in surface roughness of the materials over time and the compatibility with dental stones in addition to the previously mentioned properties. The purpose of the present study was to evaluate the changes in surface conditions of tissue conditioners over time while stored in water, and determine compatibility with Type 3 and 4 dental stones. It was hypothesized that the surface quality of dental stone casts made from tissue conditioners would be influenced both by the type of tissue conditioner and dental stone, and that the quality of the tissue conditioner would decrease with exposure to a wet environment.

MATERIAL AND METHODS

Tables I and II list the 3 tissue conditioners and 4 dental stones (Type 3 and 4)[21] used in this investigation. Immediately after mixing the powder and liquid of the tissue conditioner, according to the manufacturer's recommendation at 23 $\pm$ 2 °C, each mixture was poured into a polypropylene container with an inner diameter of 18 mm and depth of 2 mm until slightly overfilled. A flat glass plate (mean roughness value, 0.008 μm) was immediately centered above the container and pressed down onto the mass of the tissue conditioner, then removed 2 hours later. Next, 5 of each of the specimens were stored in distilled water at 37 °C for 0 or 24 hours, or 3, 7 or 14 days after preparation and the containers containing the tissue conditioners were boxed with wax (Boxing Wax – X-Thin; Heraeus Kulzer, South Bend, Ind) after the immersion. The dental stone and water were mixed in a water/powder ratio recommended by the manufacturer in a rubber bowl by hand and then mechanically under a vacuum for 15 seconds. Each dental stone mixture was then poured over the surface of each tissue conditioner specimen under gentle vibration, and was stored in air at 23 $\pm$ 2 °C for 60 minutes. Subsequently, the dental stone cast was removed from the tissue conditioner and evaluated. A total of 25 specimens were produced for each tissue conditioner/stone cast combination, which resulted in 5 specimens of each combination for each time period of water immersion.

The surface roughness values of the dental stone casts from the tissue conditioners were determined with a profilometer (Surfcorder SE-3000; Kosaka Laboratory Ltd., Tokyo, Japan) with a tracing length of 2.5 mm and cut-off value of 0.8 mm.[17] Mean surface roughness (R_a) values were determined as the average of the centerline values and recorded in microns. Five measurements for each specimen were made and averaged. A vinyl polysiloxane impression material (Examixfine-injection type; batch No. 020691, GC Corp., Tokyo, Japan) was used as a control specimen (n=5) as previously reported,[7] as it was considered to be nearly ideal in compatibility with dental stones and detail reproduction as an impression material.

Reproduction of the surface details of the stone casts made from the tissue conditioners was also determined according to the International Organization for

Standardization (ISO) specification 4823 for elastomeric impression materials.[22] The dental stone casts made from the tissue conditioners were prepared using a ruled test block with a series of 3 parallel lines, 20, 50, and 75 μm in width, intersected by 2 fiducial lines. The mixed tissue conditioner was poured into a ring mold and the test block was pressed down onto the material, then removed 2 hours after mixing. The specimens were stored in distilled water at 37 °C for the same time periods used in the surface roughness test. The mixed dental stone was then poured over the surface of the tissue conditioner under gentle vibration and removed 60 minutes after mixing.

The dental stone casts were examined under low-angle illumination at a magnification ranging from 4 to 12×. The finest line reproduced over the full length of 25 mm between the intersection lines was recorded. Three tests for each combination were performed, as stipulated by the ISO specification. The final result for evaluation was the finest line reproduced by at least 2 casts. The detail reproduction of the dental stones from Examixfine was also determined.

Mean R_a values and standard deviations (SD) of the 5 specimens of each tissue conditioner/stone cast combination were calculated. Comparisons of R_a values were subjected to a 3-way analysis of variance (ANOVA), and the contribution ratios (ρ) of type of tissue conditioner, type of dental stone, time of immersion in water of the tissue conditioners, and interaction for R_a values were also determined as follows:[23]

$$\rho_i\ (\%) = \text{net variation of } i \,/\, \text{total variation}$$
$$= (S_i - f_i \times V_e) \times 100 \,/\, S_T$$

$$\rho_{ij}\ (\%) = \text{net variation of } ij \,/\, \text{total variation}$$
$$= (S_{ij} - f_{ij} \times V_e) \times 100 \,/\, S_T$$

$$\rho_{ijk}\ (\%) = \text{net variation of } ijk \,/\, \text{total variation}$$
$$= (S_{ijk} - f_{ijk} \times V_e) \times 100 \,/\, S_T$$

where ρ_i is the contribution ratio of factor i; S_i the sum of the squares due to the main effect of factor i; f_i the degree of freedom associated with the factor i; V_e is the error variance (residual mean squares); S_T is the total sum of the squares; ρ_{ij} is the contribution ratio of the interaction between factors i and j; S_{ij} is the sum of the squares due to the interaction of i x j; f_{ij} is the degree of freedom associated with the interaction of i x j; ρ_{ijk} is the contribution ratio of the interaction among factors i, j and k; S_{ijk} is the sum of the squares due to the interaction of $i \times j \times k$; and f_{ijk} is the degree of freedom associated with the interaction of $i \times j \times k$. Essentially, ρ is the same as the square of the coefficient of correlation. Although the coefficient of correlation is useful only in the case of a linear relationship between 2 variables, ρ is a more general concept which can be applied despite the relationship.[23] ρ indicates the percentage that each factor contributes to the total variation in the obtained results. This calculation was used to determine how much the R_a values were attributable to the main effects of the factors (type of tissue conditioner, type of dental stone, time of immersion in water of the tissue conditioners) and the interaction effect between those factors. The differences among the different types of tissue conditioners and among types of dental stones were also determined using Student-Newman-Keuls test (α=.05).

RESULTS

The 3-way ANOVA results indicated significant differences among the tissue conditioners ($P<.0005$) and significant effects by the dental stones ($P<.0005$) and time of immersion in water ($P<.0005$) for the R_a values of the dental stone casts made from the tissue conditioners (Table III). However, a wide range of contribution ratios for the values was found among the factors. Among all the factors, the R_a values were most influenced by time of immersion (tissue conditioner: ρ=19%; dental stone: ρ=1%; time of immersion: ρ=37%). Significant interaction between the tissue conditioners and time of immersion ($P<.0005$; ρ=35%) and among the tissue conditioners, dental stones, and time of immersion ($P<.0005$; ρ=2%) also demonstrated that the R_a values from some of the types of tissue conditioners were affected more by the time of immersion.

The mean R_a values of the dental stone casts made from the tissue conditioners not immersed in water ranged from 0.81 to 1.24 μm (Figs. 1, 2, and 3). The Visco-gel/New Fujirock combination showed the least surface roughness, while the Soft-conditioner/New Plastone combination was the roughest. Surface roughness of the tissue conditioners immersed in water for 24 hours ranged from 0.94 to 1.56 μm (Fig. 4). Every stone cast made from COE-comfort and Visco-gel was significantly smoother ($P<.05$) than those from Soft-conditioner. No significant differences were found among the R_a values of the dental stone casts from COE-comfort and Visco-gel.

The R_a values of all tissue conditioner/stone cast combinations tended to increase with time of immersion in water of the tissue conditioners (Figs. 1, 2, 3, and 5). However, large differences in changes in surface roughness with time were found among the tissue conditioners. The stone casts made from Visco-gel were significantly smoother ($P<.05$) than those made from COE-comfort from 3 to 14 days of water immersion except for the Capstone DF and New Fujirock casts in combination with COE-comfort at 3 days. Every stone cast from Visco-gel also showed lower R_a values than those from Soft-conditioner from 3 to 14 days of immersion, though there were no statistically significant differences at 7 and 14 days. The dental stone casts from COE-comfort showed almost the same R_a values as those from Visco-gel until 24 hours of immersion, and then the values dramatically increased from 3 to 14 days of immersion. COE-comfort showed a more marked increase in R_a values over time than the other 2 materials. Dental stone casts from Soft-conditioner showed higher R_a values than those from the other 2 tissue conditioners until 24 hours of immersion. These values were intermediate to Visco-gel and COE-comfort at 7 and 14 days.

The influence of the type of dental stone was small, as demonstrated by the contribution ratios determined from ANOVA testing (Table III), though significant differences were found among the R_a values of the 4 types of dental stones in some tissue conditioners and immersion time ($P < .05$).

The R_a values of the Capstone DF, New Plastone, Die Stone, and New Fujirock casts made from Examixfine were 0.69 ± 0.09 μm, 0.69 ± 0.06 μm, 0.79 ± 0.05 μm, and 0.60 ± 0.02 μm, respectively. All values of the tissue conditioner/stone cast combinations from specimens immersed for 0 hours to 14 days demonstrated significantly higher R_a values ($P < .05$) than all of the Examixfine/stone cast combinations, except for the Visco-gel/New Plastone, Visco-gel/Die Stone and Visco-gel/New Fujirock combinations not immersed in water. No significant differences were found among the R_a values of those 3 combinations and the Examixfine/Die Stone combination, or between the Visco-gel/New Plastone combination and Examixfine/Capstone DF combination.

Table IV shows the detail reproduction of each tissue conditioner/stone cast combination. All stone casts made from Soft-conditioner and New Plastone and Die Stone made from Visco-gel without immersion in water reproduced the 20 μm-line, while the other combinations reproduced the 50 μm-line. All Soft-conditioner/stone cast combinations showed a continuous and well defined 50 μm-line from 24 hours to 7 days of water immersion. However, no stone casts from COE-comfort and Visco-gel reproduced any line after 24 hours of immersion. Examixfine reproduced the 20 μm-line with all of the tested dental stones.

DISCUSSION

The hypothesis that the surface quality of stone casts from tissue conditioners would be influenced by the type of tissue conditioner used and that the quality would degrade with aging time of the tissue conditioners was accepted. However, the influence of the type of dental stone was found to be considerably lower than that of the type of tissue conditioner and time of immersion in water of the tissue conditioners.

The results from the present study indicated that the surface roughness of dental stone casts made from tissue conditioners was more greatly influenced by the time of immersion in water of the tissue conditioners than by the type of tissue conditioner or dental stone used, as evidenced by the contribution ratios determined by 3-way ANOVA. Although the type of tissue conditioner also had an influence on surface roughness, the influence of the type of material was smaller than that of immersion time. The surface roughness of dental stone casts increased with time of immersion in water of the tissue conditioners because of rougher surface condition of the tissue conditioners with time. The deterioration in surface condition of the tissue conditioners with time was likely due to the leaching out of the low-molecular-weight plasticizer and, especially, ethyl alcohol from the materials,[11,16] along with water absorption.[8] There was almost no relationship between type of dental stone and compatibility with tissue conditioners, perhaps because the influence of deterioration of the tissue conditioners may be greater than that of the specific interactions between each type of tissue conditioner and dental stone.

Visco-gel showed a smoother surface quality during immersion in water than the other materials, probably because the liquid portion of this material consists of a considerably lower percentage of ethyl alcohol (4.9 wt%), a higher-molecular-weight ester, butyl phthalyl butyl glycolate (mol. wt, 336; 86.9 wt%) and dibutyl phthalate (mol. wt, 278; 8.2 wt%).[11] COE-comfort contains a lower-molecular-weight ester, benzyl benzoate (mol. wt, 212; 87.3 wt%)[11] and has a lower powder/liquid ratio (0.90), and thus a larger amount of ethyl alcohol, and showed a greater increase in surface roughness over time. The changes of Soft-conditioner over time were intermediate between those of Visco-gel and COE-comfort. The surface conditions of tissue conditioners would be attributed to chemical composition, molecular weight and particle size distribution of polymer powders, in addition to the composition of the liquids. Further research into the relationships among surface conditions and the composition and structure of the materials is necessary.

Tissue conditioners are used for tissue conditioning, functional impression making, provisional relining, and in implant therapy. Their physical properties, such as viscoelastic properties[6] and dimensional stability,[4,7,8] which make them suitable for these varied purposes, are different among the different types.[6] That is, if the material is near ideal for one purpose, it may not be ideal for another. Thus, a single type of tissue conditioner may not be capable of fulfilling all of the intended uses equally well. It was found that some of the present tissue conditioners were not suitable for making a functional impression, because changes in the surface roughness over time varied considerably among the types tested. When using a tissue conditioner for making a functional impression, the material should flow and register the mean shape of the denture-bearing mucosa under functional stress, such as mastication, speech, swallowing and parafunction. A functional impression should remain intraorally for at least 24 hours before pouring the dental stone cast in order to avoid distortion of the impression surface caused by insufficient elastic recovery of the tissue conditioners.[5] The material should also have high compatibility with the dental stone and dimensional stability.

Visco-gel produced smoother surfaces on the dental stone and exhibited only minimal changes in surface roughness over time in the present study. Furthermore, a previous study reported that Visco-gel behaved in a more stable manner dimensionally.[8] From the standpoint of surface quality and dimensional stability, Visco-gel may be more suitable for making a functional impression than the other 2 types of materials tested. The values for surface roughness of the dental stone casts made from the vinyl polysiloxane impression material used in this study ranged from 0.60 to 0.79 μm. Although the surface condition of most of the dental stone casts from the tissue conditioners was not better than that of casts produced from the vinyl polysiloxane impression material, Visco-gel and Soft-conditioner during 14 days of water immersion (0.81 to 1.73 μm and 0.92 to 1.88 μm, respectively) and COE-comfort until approximately 3 days of immersion (0.87 to 1.61 μm) produced relatively smooth surfaces. However, to obtain accurate information regarding the denture-bearing mucosa, it appears that the recommended period for making a functional impression would be 24 hours after application for COE-comfort and Soft-conditioner (0.94 to 1.01 μm and 1.50 to 1.56 μm, respectively), or between 24 hours and 3 days for Visco-gel (0.93 to 1.13 μm). Clinically, the authors have observed that the surface of Visco-gel remains glossy after remaining in the mouth for a few days. There are many factors involved with the surface conditions of tissue conditioners, including the effects of saliva, denture cleansers, thermal cycling, and masticatory force. Thus, it should be noted that changes in surface roughness of the materials over time clinically may be different from those obtained in the present study. When the material is applied to a denture, the layer must have sufficient bulk and a liner thickness of approximately 2 mm is recommended[1] for making accurate functional impressions. Furthermore, it has been reported that the application of coatings such as Monopoly, a poly (methyl methacrylate) syrup made of 1 part clear polymer powder to 10 parts heat-polymerized monomer, is effective in maintaining the surface integrity and softness of a tissue conditioner over a relatively long period of time.[15] Further research on the compatibility of coatings with dental stones and their durability is necessary for determining their efficacy in making functional impressions.

When not immersed in water, all of the present tissue conditioners complied with the minimum detail reproduction (50 μm-line) on the dental stones specified in the ISO specification for elastomeric impression materials,[22] though some combinations produced a better surface detail (20 μm-line). The lines faded and lost sharpness over time in water, probably due to the deterioration in surface and especially flow properties of the materials. Application of a tissue conditioner with a larger flow property will lead to a great diminution of the lines over time under the present experimental conditions, owing to its flow. However, in clinical situations, tissue conditioners are exposed to instantaneously applied forces caused by mastication and a continuous weak force caused by changes in the denture-bearing mucosa. Therefore, materials with larger flow properties may flow more readily and more effectively register the surface details in the mouth. It should be noted that the present method did not necessarily simulate the clinical situations. Considering the 2 previously mentioned phenomena, it is necessary to establish an experimental method for determining surface detail reproduction of dental stone casts from tissue conditioners.

An ideal tissue conditioner used as a functional impression material should have high compatibility with the dental stones and a smooth surface equivalent to that of elastomeric impression materials. Furthermore, those properties should be maintained intraorally until a functional impression is formed. However, since it appears that the ideal material does not currently exist, further research and development are needed to develop improved materials that meet the previously mentioned requirements. Finally, it is important to elucidate tissue conditioners that are suitable for making a functional impression and obtain a good understanding of the appropriate period of application for each material, as there is a wide range of compatibility with dental stones and changes in surface conditions over time among the available materials.

CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. The tissue conditioner type (contribution ratio ρ=19%) and especially the period for making functional impressions (ρ=37%) were found to have a major influence in the surface quality of dental stone casts from tissue conditioners. In contrast, the type of dental stone (ρ=1%) was of lesser importance.
2. The surface roughness of dental stone casts from tissue conditioners increased significantly with immersion time of the tissue conditioners. From the standpoint of surface condition, the period recommended for forming functional impressions would range from 24 hours to 3 days after application, dependent upon the type of tissue

conditioner used.

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Table I. Tissue conditioners tested

Material	Batch no. powder - liquid	Manufacturer	Composition of Powder[10]	Composition of Liquid[11] Plasticizer	EtOH (wt%)	Powder / liquid ratio by weight
COE-comfort	080596D-091396A	GC America Inc., Chicago, Ill.	PEMA (poly (ethyl methacrylate))	BB (benzylbenzoate); DBP (dibutyl phthalate)	8.2	0.90
Soft-conditioner	151281-151281	GC Corp., Tokyo, Japan	PEMA (poly (ethyl methacrylate)); PBMA (poly (butyl methacrylate))	DBP (dibutyl phthalate)	10.0	1.37
Visco-gel	0004000985-0004000590	Dentsply De Trey GmbH, Konstanz, Germany	PEMA (poly (ethyl methacrylate)); PMMA (poly (methyl methacrylate))	BPBG (butyl phthalyl butyl glycolate); DBP (dibutyl phthalate)	4.9	1.21

Table II. Dental stones tested

Material	Batch no.	Manufacturer	ISO Type[21]
Capstone DF	030302	Shofu Inc., Kyoto, Japan	3
New Plastone	0102161	GC Corp., Tokyo, Japan	3
Die Stone	0011156	Heraeus Kulzer, South Bend, Ind.	4
New Fujirock	0007031	GC Corp., Tokyo, Japan	4

Table III. Three-way ANOVA results for surface roughness (R_a) of dental stone casts made from tissue conditioners

Source	*df*	Sum of squares	Mean square	F	Significance of F	Contribution ratio ρ (%)
Tissue conditioner	2	52.376	26.188	706.267	0.000	19.3
Dental stone	3	2.302	0.767	20.691	0.000	0.8
Time	4	101.579	25.395	684.874	0.000	37.4
Tissue conditioner × Dental stone	6	1.026	0.171	4.613	0.000	0.3
Tissue conditioner × Time	8	95.731	11.966	322.726	0.000	35.1
Dental stone × Time	12	3.732	0.311	8.387	0.000	1.2
Tissue conditioner × Dental stone × Time	24	5.877	0.245	6.604	0.000	1.8
Residual	240	8.899	3.708×10^{-2}			4.1
Total	299	271.521				100.0

Table IV. Detail reproduction on dental stone casts made from 3 different tissue conditioners

	Time immersed (days)				
	0	1	3	7	14
COE-comfort / Capstone DF	50	-	-	-	-
COE-comfort / New Plastone	50	-	-	-	-
COE-comfort / Die Stone	50	-	-	-	-
COE-comfort / New Fujirock	50	-	-	-	-
Soft-conditioner / Capstone DF	20	50	50	50	75
Soft-conditioner / New Plastone	20	50	50	50	75
Soft-conditioner / Die Stone	20	50	50	50	50
Soft-conditioner / New Fujirock	20	50	50	50	75
Visco-gel / Capstone DF	50	-	-	-	-
Visco-gel / New Plastone	20	-	-	-	-
Visco-gel / Die Stone	20	-	-	-	-
Visco-gel / New Fujirock	50	-	-	-	-

- represents None in μm

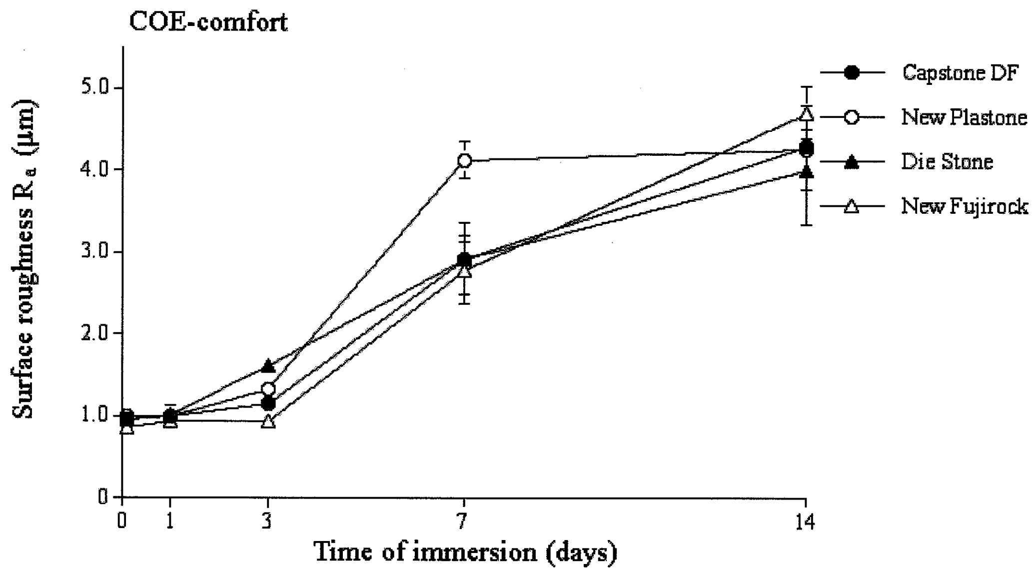

Fig. 1. Variations of surface roughness (R_a) values of dental stone casts made from COE-comfort with time of immersion in water.

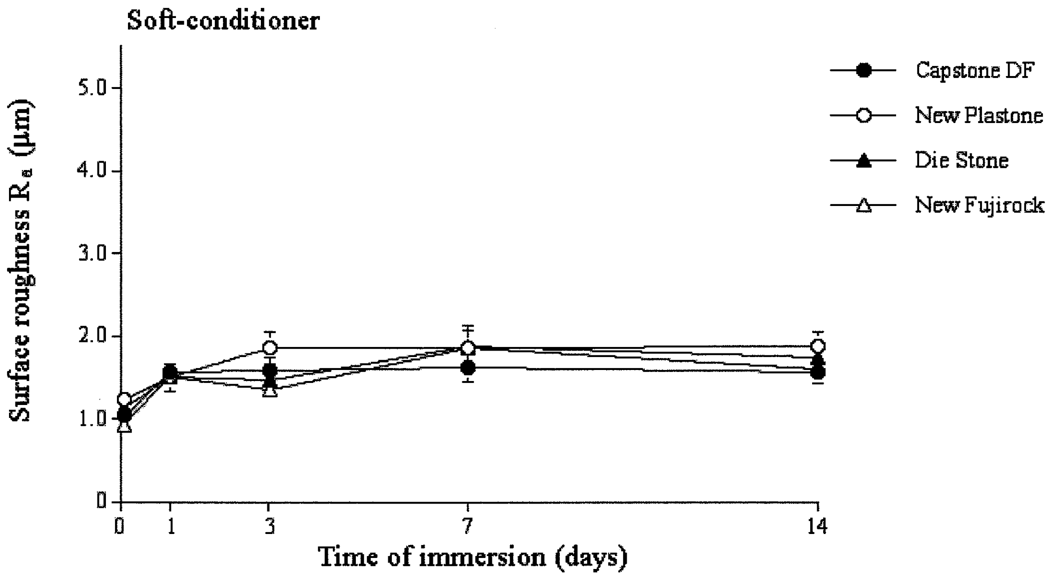

Fig. 2. Variations of surface roughness (R_a) values of dental stone casts made from Soft-conditioner with time of immersion in water.

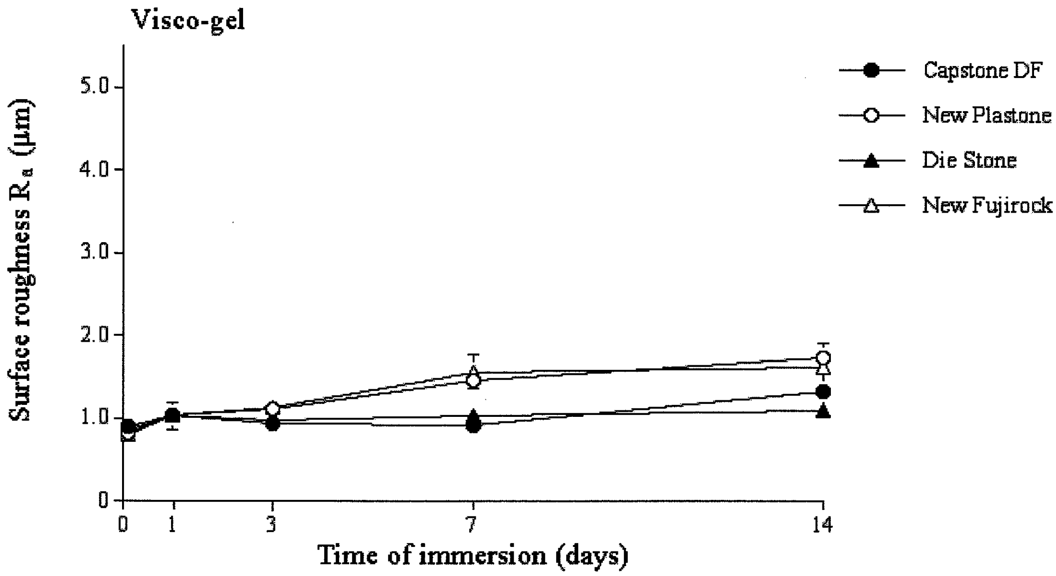

Fig. 3. Variations of surface roughness (R_a) values of dental stone casts made from Visco-gel with time of immersion in water.

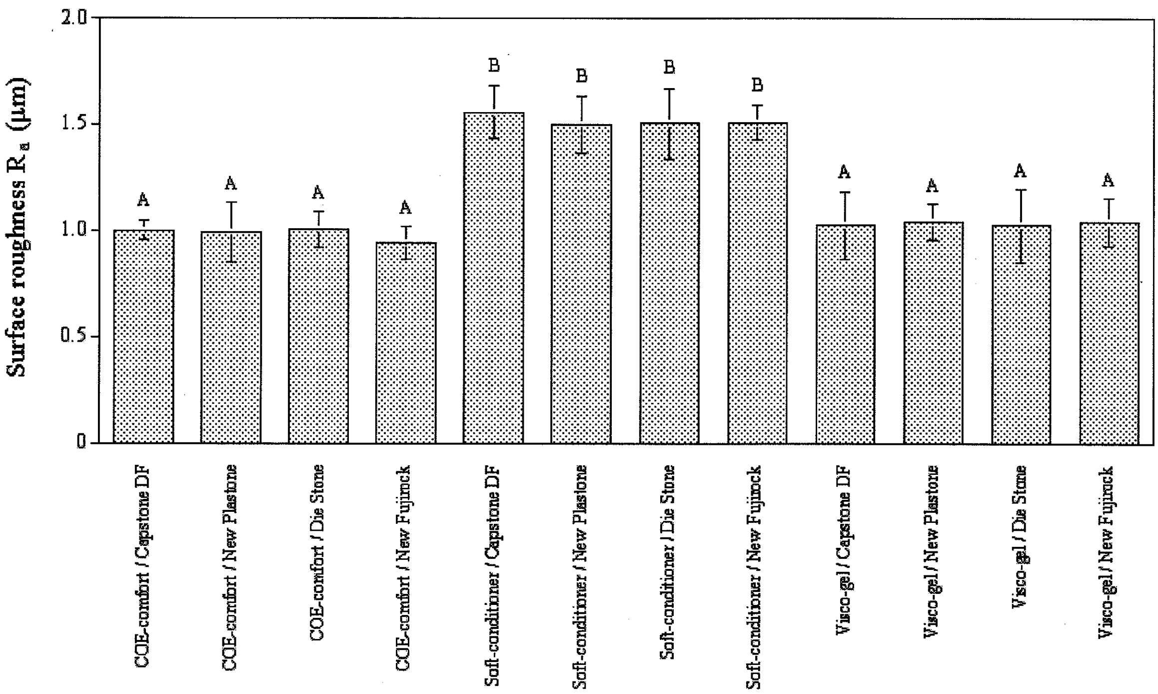

Fig. 4. Surface roughness (R_a) values of dental stone casts made from 3 tissue conditioners after being immersed in water for 24 hours. Identical letters indicate no statistical differences.

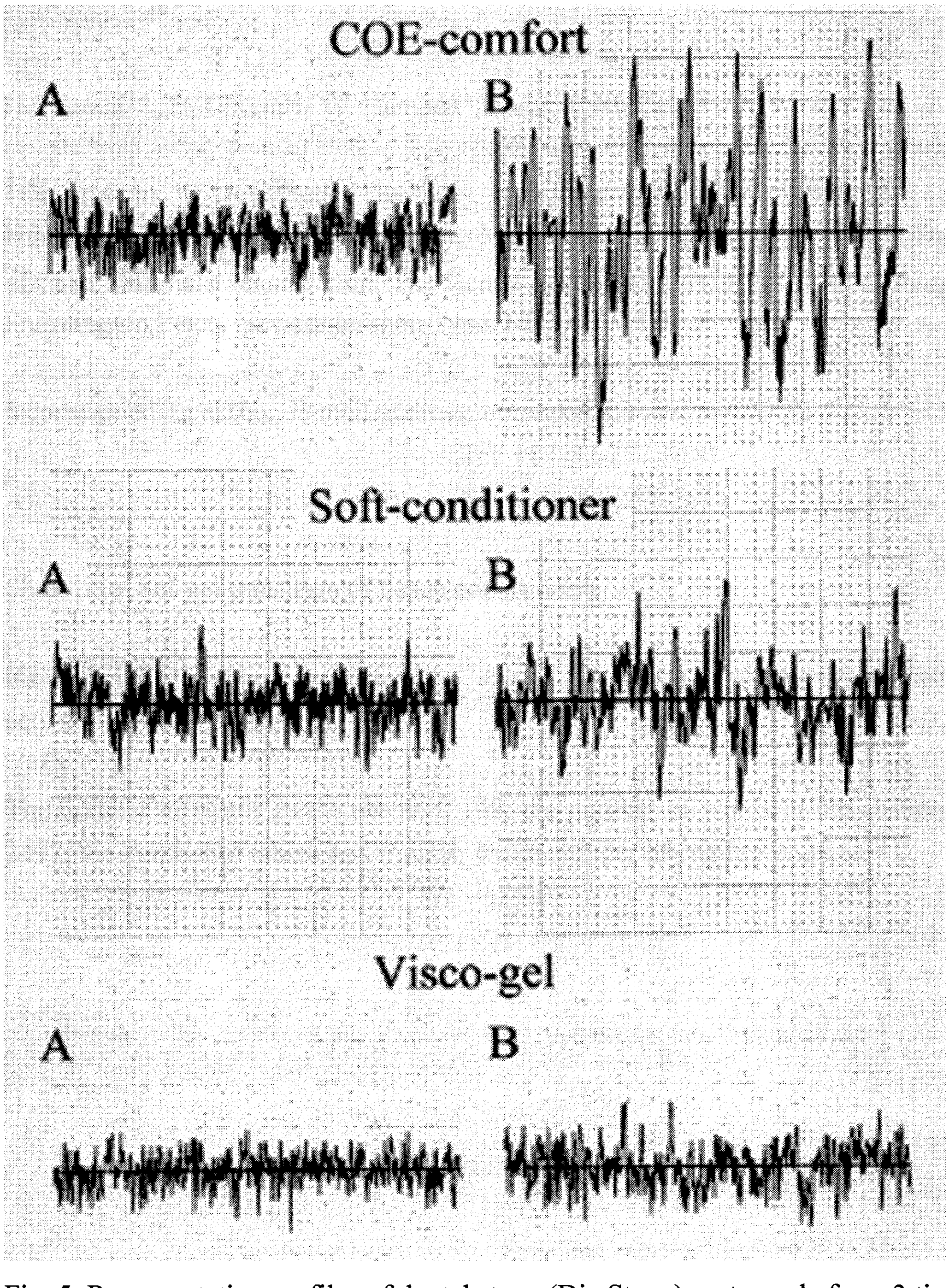

Fig. 5. Representative profiles of dental stone (Die Stone) casts made from 3 tissue conditioners without immersion in water (A) and after 14 days of water immersion (B).