Silicone (BIODUR) Viscosity and Impregnation in Plastination

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This paper deals with the analysis of temperature effect over the viscosity of the polymeric mixtures used in plastination studies. Two reaction mixtures were prepared respecting the standard protocol of the Biodur S10/15 technique. For these two mixtures, viscosity measurements were performed at -25 °C, +20 °C and +40 °C, after one day, one week, two weeks, three weeks and four weeks, respectively after preparation. These parameters were chosen rationally, since the standard impregnation time for the cold silicone method is three weeks. These results were also corroborated to the acetones' vapor pressure, showing that for Biodur silicone, impregnation at room temperature is possible. A maximum of two weeks of impregnation was determined for S10, while for S15, this could be realized over a period of three weeks.

Keywords: silicone viscosity, impregnation, S10/S15 technique, room temperature, cold method plastination

One of the most used techniques in plastination is the silicone one. The goal of plastination is to replace tissue fluid with a curable polymer. Once the polymer is inside the specimen, it is cured (hardened) to keep the silicone in the specimen and to make the specimen dry. All over the world there are two common ways for the silicone technique: impregnation at low temperature (-25 °C) or impregnation at room temperature [1, 2]. The first technique was the cold impregnation method, at -25 °C, introduced by von Hagens in 1979 [3], while in the mid-nineties, the room-temperature technique was promoted by Corcoran industries in the USA. The basic difference in the preparation methodology, excluding the polymers, is the sequence in which polymer, catalyst chain extender and cross-linker are combined. The basic cold Biodur S10 process combines the silicone polymer with the catalyst and chain extender to serve as the impregnation-mixture [4]. The Dow™/Corcoran/ Room-temperature method combines the silicone polymer with the cross-linker [5, 6]. This mix yields a stable impregnation-mix even when kept at room temperature.

During curing, the impregnation reaction-mix within the specimen is cross-linked and the specimen is made dry. This is a two-step process consisting of chain extension and cross linkage of polymer. Chain extension of the silicone molecules is an "end to end" alignment, thus forming longer chains via the chain extender portion of the Biodur S3 impregnation-mixture which is now in the specimens. Theoretically, chain extension starts when the Biodur S3 (catalyst & chain extender) and Biodur S10 polymer are mixed. However, this reaction is slowed dramatically by low temperatures (below -15°C). The polymer reaction-mixture may be kept for a few years in the cold (below -25°C). Longer chains result in more viscous polymer. At room temperature, the elongation occurs at an increased rate. In six to ten months, at room temperature (RT), the reaction-mixture will become too viscous for impregnation. Cross-linking or connecting the silicone polymer molecules side to side, forming a firm 3-D meshwork of the silicone polymer, is caused by the Biodur S6 (cross-linker). The catalyst (S3) role is to increase the reaction rate between the S10 molecules and the S6 cross-linker. The S6 is more reactive in its vapor (gaseous) state, hence the term "gas curing" is used. The vaporized S6 diffuses onto the impregnated specimen's surface. The cross-linking reaction starts on the specimen's surface and proceeds inward to the depths of the specimen [7].

Our study refers to the standard Biodur S10/15 technique. As known, the standard protocol uses low temperature for impregnation. But, a lot of plastinators would like to impregnate in room temperature due to different reasons. We know that this is possible even with the S10/15 polymer, if we reduce the impregnation time. As stated before, the pot-life of the impregnation mixture (S10/15 +S3) is greatly reduced at room temperature. The goal of our study was to determine the viscosity of the S10+S3 and S15+S3 mixtures under different temperature conditions, in order to determine the proper impregnation time.

Experimental part

Two reaction mixtures were prepared respecting the standard protocol of the Biodur S10/15 technique [7]. First we mixed 1kg of S10 with 10 mL of S3 and second 1kg of S15 with 10 mL of S3. The obtained quantity was split into three equal parts for each polymer mixture, in order to determining the viscosity at -25°C, at room temperature (+20 °C) and at +40 °C. For each polymer mixture, we had three receptacle and the measurements were done by a NDJ-4 Rotational Viscometer (Green Technology, China).

NDJ series Rotational Viscometer is designed for the determination of viscosity and rheological behavior of fluids and semi-fluids.

Results and discussions

The measurements were performed at -25°C, +20°C and +40 °C. As three weeks is the standard impregnation time for the cold silicone method, we measured the

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Time / Temperature	-25 °C	+20 °C	+40 °C
1 day	4000	590	230
1 week	4130	820	1690
2 weeks	4150	1080	12310
3 weeks	4170	2730	80000
4 weeks	4310	4400	>100000

Table 1
VISCOSITY OF THE S10+S3 MIXTURE UNDER DIFFERENT TEMPERATURE CONDITIONS (VALUES IN mPa·s)

Time / Temperature	-25 °C	+20 °C	+40 °C
1 day	455	42	21
1 week	460	66	186
2 weeks	475	192	1375
3 weeks	481	281	8100
4 weeks	492	590	58900

Table 2
VISCOSITY OF THE S15+S3 MIXTURE UNDER DIFFERENT TEMPERATURE CONDITIONS (VALUES IN mPa·s)

viscosity of the S10 and S15 mixture after one day, one week, two weeks, three weeks and four weeks, respectively. The results of the measurements are presented in table 1 and 2.

The impregnation time in the standard low temperature S10/S15 protocol is three weeks. This time period permits us to increase slowly the vacuum and prevent the reaction mixture to get thick. By mixing S3 with S10/15, the extension of the polymer chains and its preparation for the final curing procedure with S6 are realized. The difference between the S10 and S15 is in their viscosity. The Biodur S10 silicone (Material Safety Data Sheet according to 2001/58/EG) has a viscosity of 400-600 mPa·s (at room temperature) and the Biodur S15 (Material Safety Data Sheet according to EG Nr. 1907/2006) - a viscosity of 50-60 mPa·s (at room temperature), that means that the S15 silicone is ten times more fluid then the S10 (water has at 20 °C a viscosity of 1 mPa·s) [8]. More fluid means that the S15 has shorter polymer chains than the S10 silicone, so we will expect that the pot life of S15 is longer. Usually the S15 polymer is used mainly for archeological specimens or organs and is not recommended for muscle specimens. The most used plastination polymer worldwide is Biodur S10. Everyone who starts plastination will use this polymer and everybody knows that after mixing S10 and S3 the mixture starts to gets viscous. The use of low temperature prevents premature thickening of the silicone mixture, but it has a disadvantage: the viscosity of the silicon mixture will increase with the decrease of temperature. Although the room temperature viscosity of S10 is between 400 – 600 mPa·s and for S15 is 40-60 mPa·s, at -25°C we measured a ten-time higher viscosity of both mixtures [9]. As the standard protocol for the S10/S15 techniques runs at -25°C we consider this viscosity, 4000-6000 mPa·s for the S10+S3 mixture (like a maple syrup) and 400-600 mPa·s for the S15+S3 mixture (melted wax at 90°C), as the standard impregnation viscosity.

When using low temperature (-25°C), the viscosity of the S10 and S15 mixture do not change allot after one month, so we can be sure that under this conditions the starting viscosity of the silicone mixture will remain almost the same during the first three weeks of impregnation. At +20°C (room temperature), the starting viscosity of the impregnation mixture is lower than in cold temperature. After one month, the viscosity of the S10 mixture is about 4400 mPa·s and the S15 mixture has a viscosity of 590 mPa·s. This indicates that the S10 got thick, but it still could be used for impregnation. At +40°C the starting viscosity of the impregnation mixtures were lower, 20 mPa·s for S15 and 200 mPa·s for the S10. After four weeks, the viscosity of S15 rises to 59000 mPa·s and the S10 over 100000 mPa·s (like a thick syrup) and could not be determined exactly. Both values indicate that at this temperature, the thickening of the silicone would not permit impregnation anymore. Due to the carried out measurements, after one week the measured viscosity is for S15 200 mPa·s and for S10 about 1700 mPa·s. Under these conditions, impregnation could be possible for both silicone mixtures. After two weeks, the viscosity increased considerably to 12310 mPa·s for S10, which makes the impregnation impossible.

Even if it was observed that at room temperature, the viscosity of the silicone mixture is still proper for impregnation, it should be taken into consideration the vapor pressure of acetone at this temperature. At low temperatures (-25°C), the vapor pressure of acetone is about 14 mmHg, but at 20 °C it becomes 200 mmHg. That means that the extraction of acetone occurs faster at room temperature. This fact has to be related with the viscosity of silicone. At low temperatures, the viscosity is higher, so the extraction of acetone will be slower, but at room temperature the extraction of acetone is faster, even due to the lower viscosity of the silicone mixture.

Making a correct diagnosis and the development of advanced surgical techniques requires good knowledge of the interrelationships of the anatomical structures [10-13]. Using MDCT angiography allows emphasizing the accuracy of vascular structures and their three-dimensional disposal [14-16]. The study of anatomical structures by dissection allows three-dimensional structures, but cannot be maintained for a long period of time without change the dimensional spatial interrelationships [17]. Using the plastinated cross sections technique, two-dimensional images are obtained, who rebuilt three-dimensional

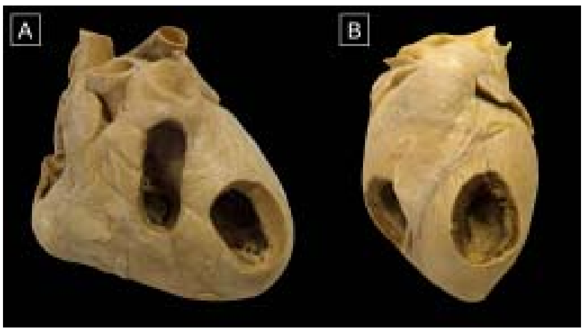

Fig. 1. Plastinated hearts in various technical conditions, using Biodur S10 technique.

A - The impregnation was conducted at 25°C for three weeks (cold method at -25°C); B - the impregnation was conducted at room temperature for ten days. [The colour figure can be viewed in the online issue, which is available at www.revmaterialeplastice.ro] structures by computer [18]. These three-dimensional images can be successfully used in training students and residents in medicine [19-20]. Unlike these methods, which presents a major advantage associated with various minor disadvantages, using the Biodur silicon (S10 and S15 techniques) ensure preservation for a long time for dissected anatomical preparations.

Conclusions

Considering both parameters, acetone extraction and viscosity, we consider that when using the Biodur silicone, impregnation at room temperature is possible. For the S10 method we could recommend a maximum of 2 weeks of impregnation, with a close supervision of acetone extraction. The acetone bubble formation during extraction should be not too intense, especially at the beginning of the process. In regard of the S15, we consider that an impregnation at room temperature could be performed over a period of three weeks.

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