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The use of a 3D laser scanner using superimpositional software to assess the accuracy of impression techniques

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Summary *Objective*. Several studies have made comparisons in the dimensional accuracy of different elastomeric impression materials. Most have used two-dimensional measuring devices, which neglect to account for the dimensional changes that exist along a three-dimensional surface.

Purpose. The aim of this study was to compare the dimensional accuracy of an impression technique using a polyether material (Impregum) and a vinyl poly siloxane material (President) using a laser scanner with three-dimensional superimpositional software.

Materials and methods. Twenty impressions, 10 with a polyether and 10 with addition silicone, of a stone master model that resembled a dental arch containing three acrylic posterior teeth were cast in orthodontic stone. One plastic tooth was prepared for a metal crown. The master model and the casts were digitised with the non-contacting laser scanner to produce a 3D image. 3D surface viewer software superimposed the master model to the stone replica and the difference between the images analysed.

Results. The mean difference between the model and the stone replica made from Impregum was 0.072 mm (SD 0.006) and that for the silicone 0.097 mm (SD 0.005) and this difference was statistically significantly, $p=0.001$.

Conclusions. Both impression materials provided an accurate replica of the prepared teeth supporting the view that these materials are highly accurate.

Introduction

The clinical success of fixed prosthodontic procedures is dependent, in part, upon the dimensional accuracy of elastomeric impression materials and impression procedures. It is important that the model of the oral cavity is an accurate three-dimensional replica, because the prosthesis is made on this model and therefore, it directly effects the fit of the indirect restoration. To date most studies assessing accuracy of impression materials have used two-dimensional techniques but recently the evolution of digital scanning systems together with software has improved the accuracy of assessments. The opportunity to assess dimensional changes over the whole area rather than around

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the margins will provide better information of the accuracy of many indirect restorative techniques.

There appears to be no consensus in the literature on the measuring device that should be used to evaluate the accuracy of impression materials. Both measuring microscopes and callipers have been used.[1-6] These manual measuring devices are easy to use and readily available but are time consuming to use, permit error due to operator fatigue, and make linear measurements between two points and do not account for the dimensional changes that exist along a 3D surface.

The American Dental Association (ADA) Specification No. 19 introduced a standardized repeatable method in 1977 for preparing and evaluating test specimens of elastomeric material.[7] This method specifies that linear dimensional changes should be measured on impressions of a steel disk 30 mm in diameter, with vertical and horizontal scribed lines as landmarks. The distances between the two intersections of the lines are determined using a measuring microscope with a micrometer-driven stage having an accuracy of 0.005 mm. One limitation to Specification 19 is that the test specimens do not represent a clinically relevant shape and thus are not subjected to the same 'path of insertion' strains that produce distortions in clinical impressions. A second limitation is that the prescribed measurements are recorded from a planar surface, ignoring the possibility of three-dimensional direction.[8] Recent studies have substituted arch-shaped dies to make impressions so that measurements are reported in three-dimensions, but most remain dependent on micrometers. It would seem that a dental cast with an arch form configuration would be more clinically relevant in the evaluation of a dental material.

Daoudi et al. investigated the accuracy of four implant impression procedures using two impression techniques and two different materials; a polyether and a poly siloxane impression material.[5] A master model was used to produce 40 different stone casts incorporating laboratory implant or abutment analogues from the different combinations using two impression techniques (the repositioning impression coping technique at the implant level and the pickup impression technique at the abutment level) and materials (President (poly(siloxane)) and Impregum F (polyether)). Variations in the resulting working casts were measured using the Reflex Microscope to derive distances and angles from the three-dimensional coordinates of optical targets that were attached to a test coping placed on the implant analogue and on a reference device positioned on the occlusal surfaces of the casts. No significant differences were found between poly siloxane and polyether impression materials for the two tested types of impression techniques. Thus it was concluded from this study that the choice of impression material made no significant difference. A similar study using two-dimensional assessments compared a head of fixture to an abutment replica impression technique using a polyether impressions.[9] The authors reported results within acceptable levels but the accuracy could only be assessed at the margins of the restoration as no assessment could be made along for the remainder of the fit of the casting.

Measurement of the dimensional changes of impression materials requires accurate equipment. The scanning laser three-dimensional (3D) digitizer can delineate x, y, and z coordinates from a specimen without actually contacting the surface. The digitizer automatically tracks coordinates with precision and stores data as the number of points on a surface with a resolution of 130 μm at 100 mm. These exacting features suggest that the laser digitizer might accurately and reliably measure the dimensions of dental impression materials while avoiding subjective errors. There have been very few studies to this date assessing the accuracy of impression materials using the laser digitizers. One study used the machine to evaluate the dimensional accuracy of a dental impression material in 1992 when the technology was not as advanced as today.[8] A steel die was machined to represent a dental arch with teeth prepared for complete crowns. Impressions and casts were made from the die, and critical dimensions were measured by two methods-one using micrometers, and the other using a scanning laser 3D digitizer. The study found that the digitizer recorded measurements were more precise than the micrometer's and virtually eliminated operator error because the acquisition of data was automatic.

Another study in 2002 used the laser digitization of casts to determine the effect of tray selection and cast formation technique on accuracy.[10] Multiple impressions of a machined steel die that resembled a dental arch were made with custom and stock impression trays and vinyl polysiloxane impression material. The impressions were poured in type V artificial dental stone and allowed to set with the tray inverted or non-inverted. The steel master die and stone casts were digitized with the Steinbichler Comet 100 Optical digitizer. 3D images of the stone casts were aligned to the 3D image of the master die and analysed with AnSur-NT software. Results obtained indicated that neither impression tray type nor cast formation technique affected the accuracy of final casts. Another study by DeLong et al. in 2001 researched into the factors influencing optical 3D scanning of poly siloxane impression materials.[11] They concluded that the digitizing performance of poly siloxane impression materials is highly material and surface angle dependent and is significantly lower than the die stone control when angles to 60° are included. It is affected to a lesser extent by surface texture.

Several studies have compared the dimensional accuracy between the different types of elastomeric impression materials, including the polyethers and the poly siloxane.[5,6] Most have used two-dimensional measuring devices, which neglect to account for the dimensional changes that exist along a three-dimensional surface.[1,3] The aim of this study was to investigate the dimensional accuracy of an impression technique using polyether impression material (Impregum) compared to a poly siloxane material (President) using a three-dimensional measuring technique with superimposition software.

Method and materials

A total of 20 impressions, 10 taken with a polyether impression material (Impregum, ESPE, Germany) and the other 10 taken with a poly siloxane (President, Coltene, Switzerland) were made of a stone die representing a human dental arch. The master die had the left hand side second premolar, first permanent molar and second permanent molar made in acrylic. The first permanent molar was prepared for a complete metal ceramic crown, with a 6° taper and a butt joint finish line. The occlusal surface of the crown preparation allowed measurement of the *x* and *y* dimensions, and the height of the preparation provided the *z* dimension.

Impressions were taken with rigid lower arch stock impression trays (Polytray, Dentsply Ltd, De Trey, England). Tray adhesive was applied to the inner surface and outer edges of the stock impression trays and the impression material was mixed according to the manufacturer's recommendations. The polyether impression material was dispensed from an automatic dispenser (Pentamix, ESPE, Germany) straight into the stock tray, and into a syringe so that it could be syringed around the crown preparation. The same volume of impression material was dispensed into the stock tray and the syringe at each time, to standardise the experiment. The stock tray was then placed over the master die in order to take the impression. In order to ensure that the trays were placed in the same position each time, an impression was taken with a customised jig as this aided correct reproducible placement of the stock tray. The impressions were allowed to set undisturbed for 5 min. After the impression was removed from the master die, it was allowed to sit undisturbed for 1 h. The impressions were poured in Orthodontic Stone (Whip Mix Gypsums, Louisville, Kentucky, USA). Twenty-eight millilitre water was mechanically mixed (350–450 rpm) with 100 g powder for 25 s. Setting time of this stone is 5–7 min and expansion on setting is 0.09%, smaller than most other gypsum products.

The stone master die and the casts were digitized with the RealScan USB Model 200 digitizer at the highest resolution of 500 lines per mm (3D Digital Corp Model 100 NY USA) to produce an image of the die and casts. Images from the digitizer were processed with special software 3D Scan Surf (Scansurf 3D Digital Corporation CT USA) into a 3D meshwork image of the die and casts. The images of the die and casts were then exported to the 3D Surface Viewer software. The image of the die was superimposed with one of the images of the casts taken with the impression. This was repeated for all 10 casts poured up in the polyether impression material, and all the 10 casts poured up in the vinyl polysiloxane impression material. The difference between the two surfaces from the original and impressions were displayed and the mean magnitude difference given.

The 3D laser (Model 200 RealScan USB scanner) captures complex 3D texture-mapped models and they are exported into a 3D ScanSurf software application where it is built and triangulated into a 3D meshwork image of the object. The scanning process is accomplished within a minute whereas the software analysis takes much longer. The software superimposes the two objects by either registering landmarks or by registering as iterative closest point (ICP). This finds an optimal fit between the two surfaces and in effect acts as a reference area. Once superimposed, the difference of the two surfaces is calculated as the shortest distance of each point on one object surface from a second object surface, within a range of 0.5 mm.

Results and data analysis

Data was analysed using Stata Release 8.2 with significance pre-determined at $\alpha=0.05$. The data is summarised graphically in Fig. 1, and univariate summary statistics are given in Table 1. The Shapiro-Francia test indicated that the data

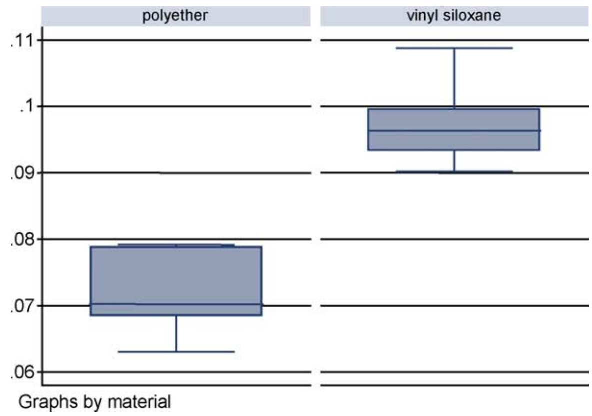

Figure 1 Shows the difference between the height recorded from digitised image of the stone casts made from the impression materials to the digitised image of the stone model with the acrylic teeth. This box plot shows the median and interquartile range for the two impression materials in millimeter.

was normally distributed, and as a consequence the two impression materials were compared using a two-sample *t*-test. The difference between the sample mean differences in the polyether and poly siloxane impressions was −0.025 mm, with a 95% confidence interval from −0.031 to −0.020 mm; the *t*-test statistic was −9.86, with 18° of freedom and an associated *p*-value of 0.001. A retrospective calculation showed the power of this test to be 1.0.

Discussion

The results showed that there was a statistically significant difference between the dimensional accuracy of polyether and poly siloxane impression materials in this study, based on the mean magnitude difference, using a 3D laser scanner. According to these results, the polyether impression material (Impregum F) had better accuracy than the poly siloxane impression material (President). The results support the work of others who reported that polyethers were more accurate than poly siloxane materials.[4] Unlike previous work the differences represent changes over the whole surface area rather than at specific points and could be considered a better discriminative test. Although, these results may be statistically significant, the difference between the average mean magnitude differences of the models poured from the two materials was only 0.025 mm. This is a very small value and may not have clinical significance.

The scanner produced a series of results that had a limited range suggesting that the technique was accurate. There was no need to undertake reproducibility since all the impressions were compared to the original model of the teeth. The accuracy of the technique suggests that this technique has much wider possibilities than measuring impression materials and could in theory be used to measure the wear of materials in the mouth. This system uses a non-contacting laser scanner called Real Scan USB (3D Digital.Corp., Model 100, NY, and USA). It is used with Scan Surf superimposition software to obtain surface difference measurements. Model 100 provides a high accuracy of up to 25 μm and is used for imaging targets that are ranging from 80 to 300 mm. It has a resolution of 130 μm at 100 mm and 180 μm at 150 mm and a field depth of 100–150 mm. The main limitation of this system is in detecting wear that is less than 25 μm or for large images greater that 300 mm. It will not detect transparent material accurately, but standard impression materials such as President or Impregum are not affected. In common with most scanning processes sharp line angles or undercuts cannot be directly measured. However, the software allows the image to be built up in a series of steps so that these areas can be measured. For this investigation this aspect of the software was not used (Fig. 2).

The laser scanned the stone surface in around 30 s meaning that the technique is quick. The analysis of the images took much longer (in the order of 30 min per scan) and therefore although the initial scanning could have clinical applications the analysis of the data still makes this particular technique a research tool. Another major benefit of the three-dimensional digitizer is that it controls investigative errors. The researcher merely sets the specimen in the device, enters the appropriate commands at the keyboard, and then reviews the automatically collected data. Conversely, with hand operated micrometers the results can be influenced by subjective bias, different bias between various operators, and errors related to such factors as fatigue, anxiety, and diurnal rhythms.

Table 1 Univariate summary statistics for the mean magnitude difference between the original die and the model.

Impression material	Mean (mm)	SD (mm)	P_{SF}
Polyether	0.072	0.0058	0.720
Poly siloxane	0.097	0.0056	0.127

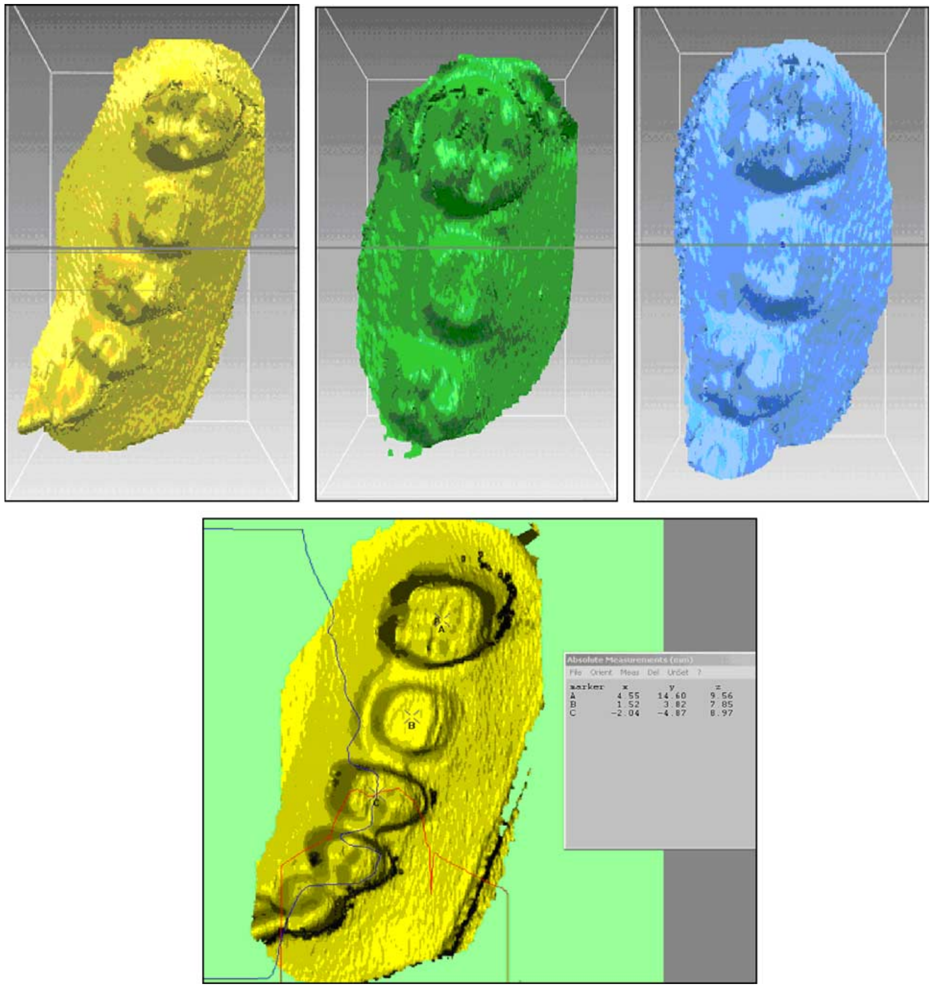

Figure 2 Shows the images captured by the scanner of the teeth. The image is built up and landmarks identified which allow superimposition of the images and so enable the differences between two similar images to be calculated.

The need to use a replication technique, in this case a stone casting, introduces inaccuracies which will affect the results. Ideally, the teeth themselves should be scanned and then the accuracy determined without recourse to impressions or stone castings. Bartlett et al. using firstly a contacting laser profilometer[12] and later a non-contacting laser profilometer[13] scanned the impression rather than a stone casting. In this study the difference in the reflectivity of the impressions and the need to compare the results meant that the impression needed to be cast in stone. Although the scanner is capable of digitising different materials with different reflectivity some adjustments to the scanner are needed and to ensure a common method was used the impressions were poured in stone. Future upgrades in the system should allow this particular problem to be overcome.

Conclusion

Three-dimensional digitizers will eventually become less expensive, require less maintenance, track faster, and be available with more standardized software. These improvements should promote their use for various projects, including analysis of dental materials. However, potential users should consider whether the improved precision associated with refined instrumentation justifies the expenditure or the continual maintenance attendant to complex technology.

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