MESH VERIFICATION TECHNIQUE FOR 3D PRINTED MODELS UTILISING 3SHAPE SOLUTIONS

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# Digital equals accuracy, right?


## 3D Printing `Mesh Verification' Technique.

Most dental labs and increasingly now a host of dental surgeries either print or receive 3D printed dental models. We are constantly told about the benefits of Digital Dental systems, but rarely warned about the steep often frustrating learning curve that goes hand in hand with adopting these and indeed any new technologies. I have been involved with digital dentistry since 2001 and have been receiving inter oral scans (IOS) for 10 years. In order to keep up with the technological advances, which are undoubtably improving our industry, we have had to constantly update our skills. The frustration is that as technology is constantly evolving with new software and hardware updates being released, so too our skills and knowledge base have to evolve accordingly.

Without doubt one of the biggest leap forwards in recent years is the improvement of IOS systems. However, being able to confidently produce accurate models for some of these systems has proved to be a challenge. Some systems exist that are are validated internally such as iTero and we are confident that they are very accurate due to the length of time we have been working with them and the reliability and successes we have had. The downside of such systems are they can be expensive and the validated models can take up to 2 weeks to to be received back into the lab!

When we started to receive IOS from 3shape there was no official model production centre available, instead we were told that there were many partner production facilities, however 3shape did not have any formal control over these centres. This was presented as a positive thing, as we were not tied to any one production facility. In reality we faced many issues with this approach. The first challenge was selecting a printing facility; we sent test prints to various partner facilities and settled on two overseas centres that returned excellent prints based on our scanned solid models. We then began sourcing our models from both of these companies. The prints we received were good, but were prohibitively expensive meaning we had to start trying 'cheaper' printing companies. The models we received back from the more cost-effective facilities were of mixed quality, hit and miss at best to just plain terrible. So, we reverted back to the previous reliable but expensive option, which we then stuck with for a number of years. Until one day I received a phone call form a very excited Steve Campbell. He had just seen a demo of a Form Labs 2 Desktop 3D printer and had decided to by it on the spot!

After the phone call from Steve I called up the company and ordered one immediately. We unpacked it 2 days later and began printing straight away. We were amazed! The prints matched the quality of the prints we were getting from outsourcing to external facilities and were working out at less than £10 each! The prints did require a lot of cleaning and post-clean curing with a

new light unit which cost over £1000 but all in all we were delighted to have found a solution to the costly time consuming process of outsourcing.

After a few weeks of trouble free prints in-lab we stopped getting prints from the production centres and solely began printing our own. This was fine for a few months then disaster struck we started getting reports from our customers that some cases were not to our usual high standards. Our report cards were coming back with contact point and bite issues, but this was only on the printed models. The alarm bells rang and we began ordering duplicate models from the production centres and after a discussion with my long time friend and colleague Dr Craig Parker we decided to put all our iTero customers back on the milled iTero models.

What we found was shocking.

Most of our in house printed models had variations from the iTero and outsourced duplicate models but we had not changed anything. We began to look at the programs and evaluated our production processes ensuring we were changing trays and liquids more often than recommended but still we got varying degrees of accuracy. We ordered a new printer and things began go back to normal. Now at this point due to the level of scrutiny we had begun to asses our prints with we realised that even the new printers and in fact the outsourced prints from the production centres were not always ‘perfect’ .

Armed with this new understanding we decided to embark on finding a solution to assess the accuracy of our prints. The first method was to have abutments & ‘jigs” manufactured directly from the IOS data (Figures 1&2), if the abutments & jig are manufactured from pure data and fit the physical print then we have verification that the print is accurate (this method still works). The problem with creating the jigs are that metal jigs are expensive and the plastic jigs, though less costly have a certain amount of flex.

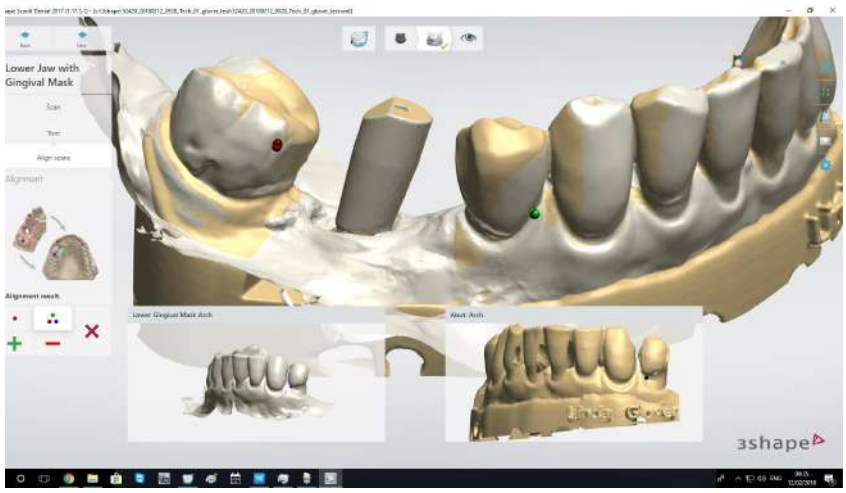
Ok we thought, on cemented restorations we can use the scan data or core files to produce a framework and if the framework and jig fit the printed model we have 2 point verification! (fig 3) If however we did not get passivity of jig or frame we would re print the model. This worked and still does for cementable options but for screw-retained options we still had to rely on jigs that were of extra cost of no use after they had been used for verification.

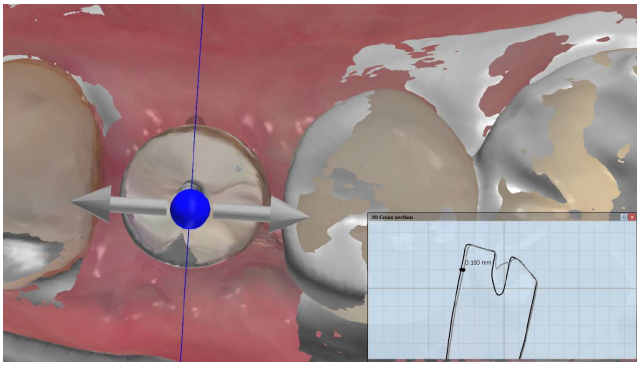
This is when I noticed Paul using the 3Shape software to measure the accuracy of 2 scans we received of the same patient and the idea hit me that we could use the software to measure the accuracy of the prints compared to the original data received from the IOS!

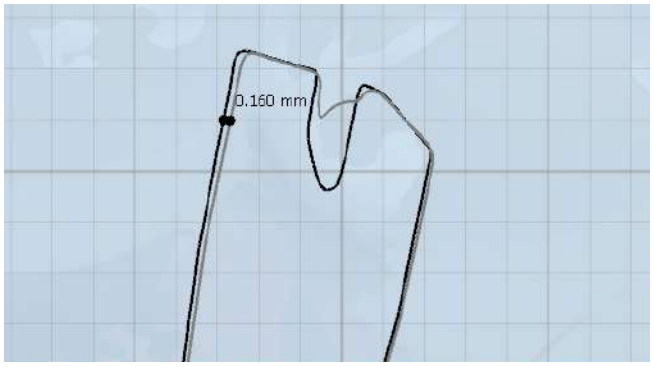
We discussed how we could realise this idea and Paul explained that we would need to source the identical scan flags the dentists use inter orally and we would be good to go!

During subsequent conversations with Craig he reminded me that this was similar to what he was doing with his iTero scans prior to sending them to the lab. He took multiple scans and merged them to check they all matched. We were all then in agreeance that this was the best pathway to assure the accuracy in the level of detail we required on printed models.

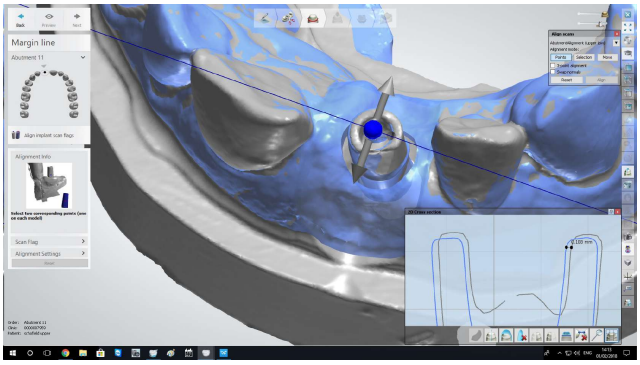
We ordered the scan flags from elos and began the tests. We printed the models and cleaned and cured them in our standardised way, then inserted the lab analogues into the models. We then screwed the scan flags, identical to those used in surgery, for each patient into the analogues. Using our 3Shape D1000 scanner we could then perform a powder free scan, import the scan we had made of our model and digitally mesh the scan with the raw scan data from the IOS (fig 4).

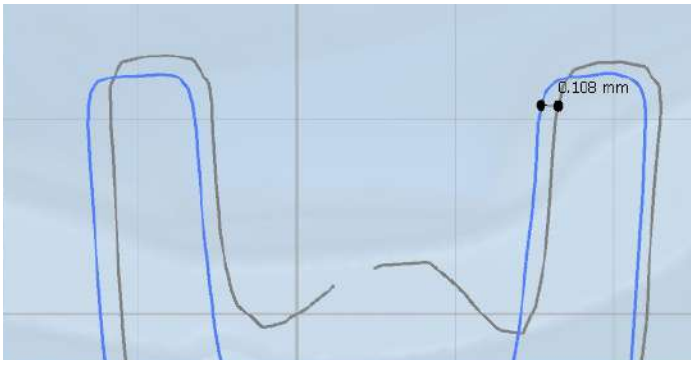


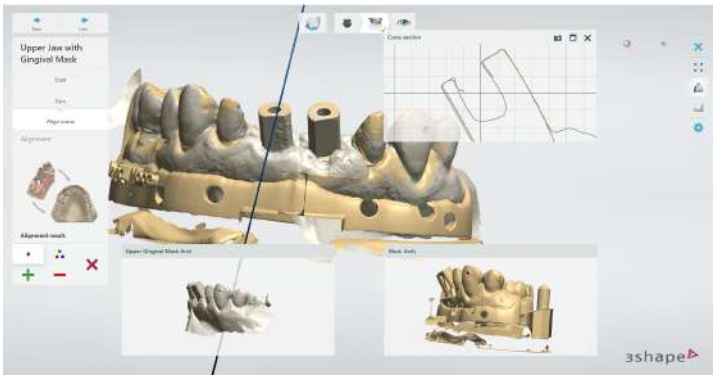


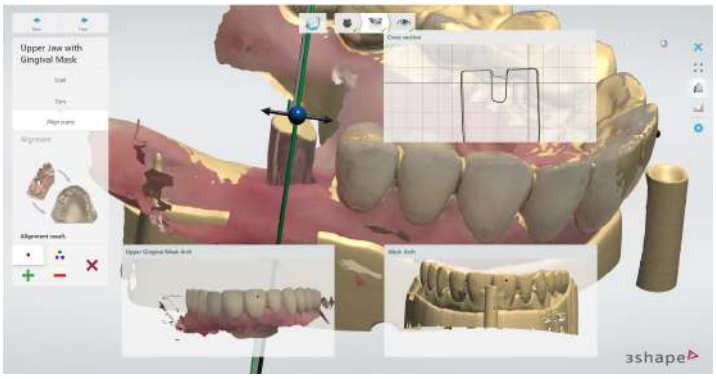

The next thing we were able to do was to utilise the 3Shape software to take sagittal and transverse cross sections at varying points of the meshed scans to obtain quantitive data on the accuracy of the prints. Fig. 5 & 6 show an inaccuracy of 0.15mm or 150 microns which was not accurate enough in our opinion.

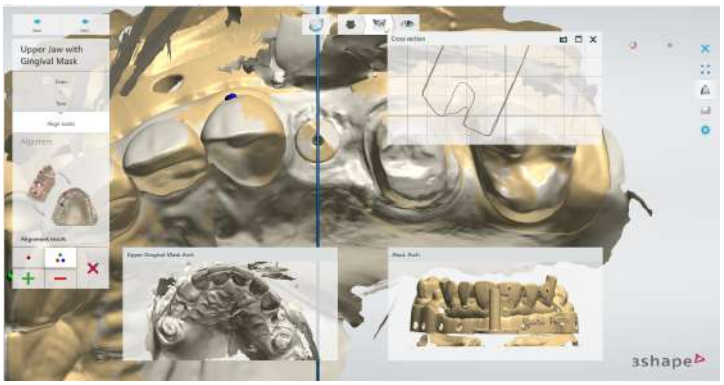


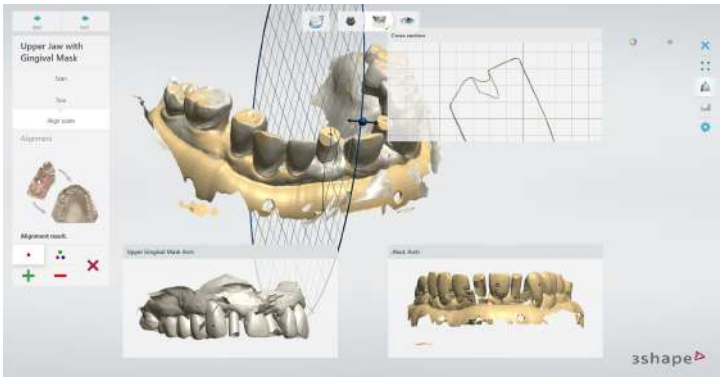



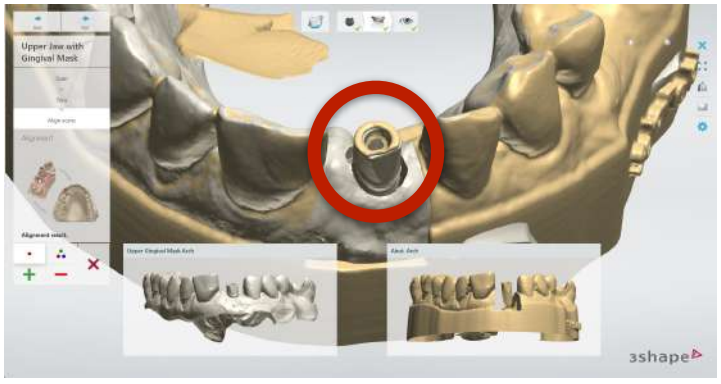

We set our acceptable limits of variation at around 0.02 mm or 20 microns as this was the the usual level of difference we found with most iTero models when compared to the raw scan data. However on occasions we found that the verified milled iTero models were falling outside this limit meshing at 0.108 mm or 108 microns variation (fig 7 & 8). On this case we printed our own and disregarded the iTero model and the case was successful. This example is a very rare occurrence and for a long time we have used the iTero models as




the benchmark for IOS. We now know that we cannot just accept that they will be true 100% of the time, we currently estimate 1 in every 50 models will have some discrepancy whilst 1 in every 5 models we print has a similar discrepancy.

After implementing this trial for several months we now feel we have a reliable way of ascertaining whether our prints are indeed accurate enough to produce high end aesthetic dental prostheses and the images below demonstrate this.

(fig 9,10,11,12) all show accurate prints to less than 20 microns of divergence from original scan data. Fig 13 shows an example of the 20% level of inaccuracy we have found in our prints. You can actually visually see the discrepancy circled in red! Scary stuff!

We now believe this method to be the most time efficient and cost effective way of verifying all our printed models and it has been added to our daily QC procedures.

We use only model resins made specifically for dental models which are designed for our versions of the printer. We also use approximately 3/4 of the cartridge before replacing with new and always fit a new tray with every change of liquid. This is substantially more frequent than the manufacturer suggests is required however we have found going beyond these limits does infact increase the frequency of prints that fail our own QC tests as explained in this study.

We also only use a cleaning system compromising of 4 wash baths, 2 for use before we post the models in the Form Wash device and 2 post Form wash cycle.

Finally we use a dedicated 3D print Light curing system recombined by manufacturer of both printers and resins to give the models the correct post processing curing cycles required.

Thank you to all the team at the lab and the fantastic clinical partners for all the input into our daily working procedures

Also special thanks to Mark Barry and the ESM digital team for 5 years of excellent support.[4]