Integration of CAD / CAM manufacturing into an existing custom contoured seating clinical and manufacturing workflow

CONSOLOR LTD
improving posture
encouraging comfort

Summary

This project involved the integration of a bespoke CAD/CAM seat manufacturing system into the Consolor custom contoured seating clinical workflow. The areas covered include changes to the clinical and manufacturing processes and logistics, digital 3D scanning, and the benefits gained and challenges encountered.

Figure 1 below shows the new robot being prepared for carving.

Aims and Objectives

To improve Consolor's clinical seating service through the use of CAD/CAM manufacturing processes by providing the following benefits:

- More efficient use of clinic time
- Potential faster turnaround of work by improving logistics
- Improved correlation of captured seat shape to finished seat shape
- Improved sub-contract manufacturing ability
- Future potential for automatic generation of patterns for manufacture of seating covers

Background

Consolor's clinical seating specialists work remotely from the manufacturing workshops. Consolor also completes subcontract seat manufacturing for clinicians and seating companies that have the skills to record best-corrected seated posture, but lack manufacturing capability.

After creating a plaster cast it needs to be dried for several days, packaged, then shipped to the workshop. This gives rise to problems of storage, turnaround time, and risk of loss or deformation of casts during transit. At the workshop these plaster casts are placed into a manual 3D pantograph milling machine to produce foam seating, or are used directly as positive moulds to produce firm seating.

In 2013 Consolor commissioned a full digital seating system workflow consisting of 3D scanners and a 7-degrees-of-freedom industrial robotic arm to carve foam seating and also to carve positive moulds over which to form firm seating. Scans can be safely emailed to the workshop from the assessment and the finished seating more closely matches the originally captured best-corrected seated posture.

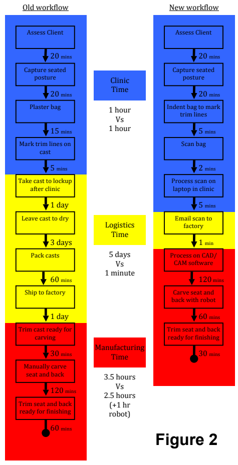
Technique

Consolor has independently sourced and integrated the hardware and software that make up its bespoke manufacturing system. A 7 axis industrial robot arm and cutting tool was specified and sourced, custom software was developed to process scans and generate cutting tool paths. Easy to use handheld digital scanners were sourced and tested. All parts of the system have been integrated into a streamlined clinical, logistical, and manufacturing workflow.

Clinical Detail

Plaster casting in clinic can be messy, slow and back aching. There are risks, costs and time delays associated with storing, drying and shipping the casts. There are potential sources of human error in the manual carving of the seating systems. This new digital system solves many of these problems. The final seat is more accurately reproduced from the original negative moulded shape, this can be proven by scanning the seat and comparing with the original scan of the best-corrected posture. It is also possible to compare new seating with existing seating in clinic, and so track progression of growth or changes in posture over time.

Figure 2 shows the difference between the new and old workflows. It is clear that the majority of the time saving is on the logistics side. It should also be noted that when the plaster cast is processed for manual carving it is essentially destroyed and can no longer be stored or used for additional seating systems. The new system allows for the indefinite storage of the seating scans, facilitating the manufacture of other products without additional moulding sessions e.g. shower chairs, armchairs.



Old workflow
Assess Client
20 mins
Capture seated posture
20 mins
Plaster bag
15 mins
Mark trim lines on cast
5 mins
Take cast to lockup after clinic
1 day
Leave cast to dry
3 days
Pack casts
60 mins
Ship to factory
1 day
Trim cast ready for carving
30 mins
Manually carve seat and back
120 mins
Trim seat and back ready for finishing
60 mins
Clinic Time
1 hour Vs 1 hour
Logistics Time
5 days Vs 1 minute
Manufacturing Time
3.5 hours Vs 2.5 hours (+1 hr robot)
New workflow
Assess Client
20 mins
Capture seated posture
20 mins
Indent bag to mark trim lines
5 mins
Scan bag
2 mins
Process scan on laptop in clinic
5 mins
Email scan to factory
1 min
Process on CAD/ CAM software
120 mins
Carve seat and back with robot
60 mins
Trim seat and back ready for finishing
30 mins

Figure 2

Manufacturing Equipment and Detail

- Robot arm (7 axis, 2.5 metre reach)
- Cutting tool (300mm long, hollow cored for efficient removal of foam chips via vacuum)
- CAD/CAM software (Rhino CAD)
- Bespoke tool path generation software.

Complete "off-the-shelf" systems are available from orthotic and prosthetic manufacturing companies, but we felt that these systems were price prohibitive and lacked flexibility in their implementation. For example, the bespoke tool path generation software was developed in collaboration with independent experts in the field and allows for both vertical and horizontal cutting paths – most systems only allow for vertical cutting paths. The system also allows for the carving of positive templates to allow the manufacture of firm seating systems such as vacuum moulded seats or Lynx/ Matrix systems.

Testing

For a period of two months, equating to the manufacture of 28 custom contoured seats, a Consolor clinician used the old and new methods of shape capture and storage. After moulding the client the bead bag was 3D scanned and then a plaster mould was also taken in the traditional way. The seats were carved by the robot. After trimming was complete only then would the plaster casts be used to check the client/seat interface shape and the profile/trimmed edges of the seat and back.

Additionally we have carried out a process of digital measurements for checking our accuracy and repeatability of client/seat interface shapes. **Figure 3** shows a sample of data collected from 3D scanned mouldings at assessment and then compares a scan of the finished seats, within CAD software. The differences between the original client/mould interface shape and the client/seat interface shape were geometrically compared.

Figure 3

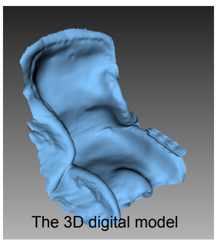
Seat	Seat Depth							
	Assessment Scan		Scan of Finished Carved Seat					
	Left	Right	Left	Difference	Accuracy(%)	Right	Difference	Accuracy (%)
1	352.73	394.94	352.86	0.13	99.96	394.8	-0.14	99.96
2	356.54	368.74	356.7	0.16	99.96	368.13	-0.61	99.83
3	435.85	434.47	437.27	1.42	99.68	437.82	3.35	99.23
4	382.71	368.81	382.15	-0.56	99.85	369.38	0.57	99.85
5	410.89	400.13	410.82	-0.07	99.98	400.37	0.24	99.94
6	484.62	476.59	482.14	-2.48	99.49	474.74	-1.85	99.61
7	437.53	412.35	438	0.47	99.89	412.56	0.21	99.95
8	361.36	401.88	361.38	0.02	99.99	402.18	0.3	99.93
9	382.24	377.49	375.89	-6.35	98.34	371.25	-6.24	98.35
10 (Like for like)	429.84	405.59	429.84	0	100.00	405.59	0	100.00
11 (Like for like)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Average	-0.74	**99.70**		-0.53	**99.65**

Seat	Hip width				
	Assess-ment scan	Scan of finished Carved Seat	Allowance for cover added	Difference - allowance for cover	Accuracy (%)
1	355.98	369.85	357.85	1.87	99.48
2	260.4	271.79	259.79	-0.61	99.77
3	N/A	N/A	N/A	N/A	N/A
4	379.16	391.44	379.44	0.28	99.93
5	300.08	312.5	300.5	0.42	99.86
6	358.75	367.02	355.02	-3.73	98.96
7	386.23	394.47	382.47	-3.76	99.03
8	297.44	312.92	300.92	3.48	98.84
9	330.09	342.88	330.88	0.79	99.76
10 (Like for like)	347.43	347.59	347.59	0.16	99.95
11 (Like for like)	N/A	N/A	N/A	N/A	N/A
				-0.12	**99.51**

We measured an average accuracy of 99.46%

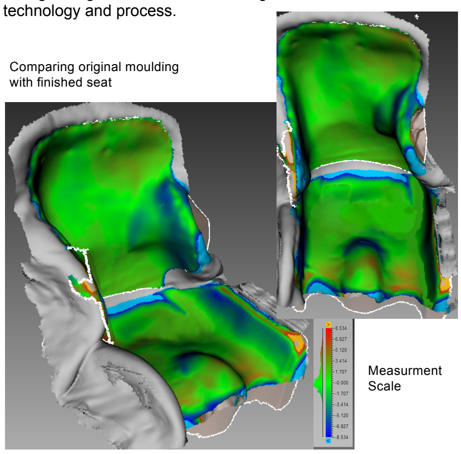
Seat	Lateral Knee Support Width				
	Assess-ment scan	Scan of finished Carved Seat	Allowance for cover added	Difference	Accuracy (%)
1	352.24	364.21	352.21	-0.03	99.99
2	309.97	312	300	-9.97	96.78
3	N/A	N/A	N/A	N/A	N/A
4	368.14	381.2	369.2	1.06	99.71
5	296.94	307.83	295.83	-1.11	99.63
6	376.34	382.9	370.9	-5.44	98.55
7	372.63	383.07	371.07	-1.56	99.58
8	283.64	295.2	283.2	-0.44	99.84
9	323.17	335.19	323.19	0.02	99.99
10 (Like for like)	384.49	385.76	385.76	1.27	99.67
11 (Like for like)	N/A	N/A	N/A	N/A	N/A
				-1.8	**99.31**

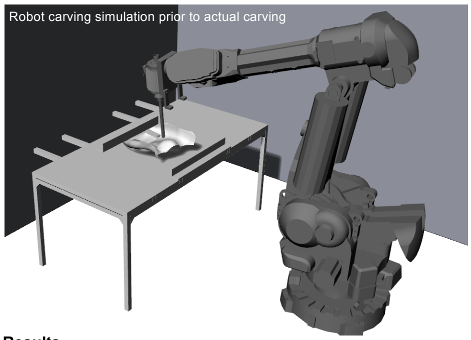
Seat	Backrest Height				
	Assess-ment scan	Scan of finished Carved Seat	Allowance for cover added	Difference	Accuracy (%)
1	544.71	518.45	543.45	-1.26	99.77
2	445.39	419.34	444.34	-1.05	99.76
3	N/A	N/A	N/A	N/A	N/A
4	497.77	469.09	494.09	-3.68	99.26
5	500.05	486.88	511.88	11.83	97.69
6	490.3	460.98	485.98	-4.32	99.12
7	538.55	511.83	536.83	-1.72	99.68
8	589.61	564.92	589.92	0.31	99.95
9	N/A	N/A	N/A	N/A	N/A
10 (Like for like)	N/A	N/A	N/A	N/A	N/A
11 (Like for like)	471.84	471.8	471.8	-0.04	99.99
				0.01	**99.40**



Seat	Trunk width				
	Assess-ment scan	Scan of finished Carved Seat	Allowance for cover added	Difference	Accuracy (%)
1	298.59	302.3	290.3	-8.29	97.22
2	225.55	238.1	226.1	0.55	99.76
3	N/A	N/A	N/A	N/A	N/A
4	305.81	315.49	303.49	-2.32	99.24
5	273.87	288.61	276.61	2.74	99.01
6	331.41	343.4	331.4	-0.01	100.00
7	286.44	297.68	285.68	-0.76	99.73
8	305.23	319.48	307.48	2.25	99.27
9	N/A	N/A	N/A	N/A	N/A
10 (Like for like)	N/A	N/A	N/A	N/A	N/A
11 (Like for like)	336.26	339.29	339.29	3.03	99.11
				-0.35	**99.17**

We examined the very small inaccuracies and many of the differences between the original and the finished shapes can be attributed to manual operations. These include manual interpretation of trim lines within software prior to sending the coding to the robot and partial manual trimming of the physical foam cushion post robot carving. We also scanned the finished seats after they were glued into their plastic shells, so if the shell had inaccuracies in it's construction this would be transferred to the finished cushion e.g. if the shell was made too wide then the cushion (being adhered to it's sides) would be pulled into a slightly wider shape. These are areas not for concern or even, arguably improvement being that they are such small differences, **0.6mm on average** (especially taking into account the medium we are dealing with is foam and very flexible) but are worth noting and give us and our clients great confidence in the new technology and process.





Results

Consolor has successfully integrated its production to the digital age! This has streamlined clinical, logistical and manufacturing processes. Assessments can be cleaner and quicker. Risks associated with drying, storing and shipping plaster casts have been eliminated. Finally, the finished seating system more accurately reproduces the originally captured best-corrected seated posture.

Discussion

In addition to the seating we have detailed here we are also carving positive moulds over which we are Vacuum Forming firm seating and draping Matrix and Lynx seating.

The primary aims and objectives of the project have been met, but further work is required to make full use of the system. This includes:

- **Subcontract seating service:** Consolor offers a subcontract seating system manufacturing service for clinicians, NHS organisations and seating companies that have the skills to record best-corrected seated posture but not manufacturing capability. This takes the form of a seating-service-in-a-box, which includes a hand-held 3D scanner and laptop, moulding bags, adjustable wheelchair, and appropriate training.
- **Expand our current offerings:** to include custom contoured lying supports and armchair inserts.
- **Produce custom contoured slings from scans:** This work is currently ongoing, and could potentially allow a client to be in a much better hoisted posture than off the shelf slings will allow by providing improvements to the correction and accommodation of postural deformities.
- **Develop and integrate automated seat cover pattern generation:** to also include fabric cutting using captured 3D data to streamline the manufacture of custom contoured seat upholstery covers.

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