Computer-Aided Design of Customized Foot Orthoses: Reproducibility and Effect of Method Used to Obtain Foot Shape

Scott Telfer, EngD, Kellie S. Gibson, BSc, Kym Hennessy, BAppSc, Martijn P. Steultjens, PhD, Jim Woodburn, PhD


Objective: To determine, for a number of techniques used to obtain foot shape based around plaster casting, foam box impressions, and 3-dimensional scanning, (1) the effect the technique has on the overall reproducibility of custom foot orthoses (FOs) in terms of inter- and intracaster reliability and (2) the reproducibility of FO design by using computer-aided design (CAD) software in terms of inter- and intra-CAD operator reliability for all these techniques.

Design: Cross-sectional study.

Setting: University laboratory.

Participants: Convenience sample of individuals (N=22) with noncavus foot types.

Interventions: Not applicable.

Main Outcome Measures: Parameters of the FO design (length, width at forefoot, width at rearfoot, and peak medial arch height), the forefoot to rearfoot angle of the foot shape, and overall volume match between device designs.

Results: For intra- and intercaster reliability of the different methods of obtaining the foot shape, all methods fell below the reproducibility quality threshold for the medial arch height of the device, and volume matching was <80% for all methods. The more experienced CAD operator was able to achieve excellent reliability (intraclass correlation coefficients >0.75) for all variables with the exception of forefoot to rearfoot angle, with overall volume matches of >87% of the devices.

Conclusions: None of the techniques for obtaining foot shape met all the criteria for excellent reproducibility, with the peak arch height being particularly variable. Additional variability is added at the CAD stage of the FO design process, although with adequate operator experience good to excellent reproducibility may be achieved at this stage. Taking only basic linear or angular measurement parameters from the device may fail to fully capture the variability in FO design.

Key Words: Computer-aided design; Orthotic devices; Rehabilitation.

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THE INCORPORATION OF integrated computer-aided design (CAD) and computer-aided manufacturing (CAM) systems into the clinical provision of prosthetics and orthotics is an approach that is receiving increasing attention.1,2 These technologies offer a number of advantages over traditional methods and provide a route to transforming orthotic design and fabrication from an artisan craft into a modern clinical speciality.3

Traditional methods for producing custom foot orthoses (FOs) begin by taking a plaster cast of the foot while it is held in the subtalar joint neutral position by the caster.4 The negative mold can then be used to create a positive cast that may be modified and used as a template around which to shape the FO. This approach is still considered the criterion standard for custom orthosis design and fabrication; however, the quality of the cast, in terms of accurate capture of plantar geometry and the correct alignment of the foot, can be heavily influenced by the skill of the clinician, and casting can be a time-consuming and messy task.5,8 A variation on this approach uses a foam impression box to obtain the negative and partial weight-bearing shape of the foot, which can then be filled with plaster to provide a positive cast.

Recently, 3-dimensional (3D) surface scanners and digitizers able to scan the foot directly have become available, meaning that accurate computer models of the foot shape can be generated.6 Based on figures from the Australian market, the use of a 3D scanner to directly capture the shape of the foot provides significant cost savings over plaster casting methods, after the initial outlay for equipment.9 Scanners can also be used to obtain a digital representation of a plaster cast or a foam impression. On combining these direct or indirect methods with the additional design freedom provided by CAD,1 the potential advantages of CAD CAM in the area of FO provision are clear. However, the combination of 3D surface scanning and CAD CAM FOs remains underinvestigated in the scientific literature. Evidence of reproducibility and comparisons with current methods would be beneficial for clinicians and health care providers who are considering using these technologies.

This study aims to determine the reproducibility of FOs generated via a commercially available orthosis design pack-
age for 6 techniques used to obtain the foot shape in terms of intra- and intercaster reliability. In addition, the effect of these techniques on the final FO design produced by the software will be determined, with the hypothesis being that the technique used to obtain the foot shape plays a significant role in the output design and the null hypothesis being that there is no shape variation between the designs. We also hypothesize that the CAD stage of FO design represents a separate, independent source of variability; therefore, reproducibility of the CAD stage of FO design will also be assessed, with intra- and inter-CAD operator reliability being tested for each of the methods.

METHODS

Before the commencement of this study, ethical approval was awarded by the institutional ethics committee (application reference number B10/56) and all participants gave informed, written consent. A convenience sample of healthy subjects was recruited, with the sample size being determined by the time and cost constraints of the study. Potential participants were excluded if they had a rigid cavus foot, based on clinical assessment by a qualified podiatrist. All randomization orders received formal training in the use of the software, used the scans to produce an FO design using the “standard orthosis from scan” mode. Both CAD operators have used the software for approximately 2 years; however, operator 1 (S.T.) was a more regular user of the software, designing 2 or 3 pairs of FOs per week in comparison to around 2 pairs per month in the case of operator 2 (K.S.G.). The scan files were recorded and randomized once again, and a second FO design was produced by both researchers to allow intra-CAD operator reliability to be determined. Each design was a three-fourth length FO, with a 4° extrinsic medial heel post. This was chosen because it was considered to represent a typical device that would be prescribed clinically for pronated feet.

The designs were exported from the CAD software in the form of 2 separate stereolithography (.stl format) files, consisting of the upper and lower surfaces of the device.

Data Analysis

The main design parameters of the FO that were used to measure the variability of the design were width of the forefoot, width at the heel of the device (heel width), overall length of the device, peak arch height on the medial side of the device, and forefoot to rearfoot angle. All design parameter measurements were taken by using a separate software package, with the exception of the forefoot to rearfoot angle, which was taken directly from the foot or cast scan.
in the CAD software. For each method of obtaining the foot shape, intra- and inter-CAD operator and intra- and intercaster reliability was assessed by using a 2-way random, single measures, absolute agreement-type intraclass correlation coefficient (ICC(2,1)). This correlation coefficient was used as opposed to the Pearson correlation coefficient because it is sensitive to the absolute size of the values in the data sets. Values range from 0 to 1, and arbitrary benchmarks, based on those used in a previous reliability study, have been adopted here to define the strength of agreement,13 with less than 0.4 suggesting poor agreement, 0.4 to .75 good agreement, and greater than .75 excellent agreement. The smallest real difference was also calculated for each of the measures to estimate the variation that can occur by chance over repeated measurements.

The 2 design parameters considered to be most important for the function and fit of the device, medial arch height and forefoot to rearfoot angle, were further analyzed to determine the effect of the different methods used to obtain foot shape. Multiple linear regressions were carried out to control for effects of the different casters and time points by using plaster casting, as the current criterion standard, as the reference variable. A one-way analysis of variance and post hoc multiple comparisons were performed by using Tukey’s test to determine whether there were significant differences between the devices generated by the various methods.

In addition, to provide an overall measure of the difference in shape of the FOs, the upper surface of each device was imported to Netfabb Studio Professional software and extruded 3mm vertically to form a solid 3D model. A Boolean subtraction operation with the relevant matched orthosis design was then performed to find the volume overlap of devices.

**RESULTS**

Twenty-two healthy participants, 10 men and 12 women, with mean age ± SD of 42.8±11.4 years, mean height ± SD of 1.72±0.1m, and mean weight ± SD of 75.2±13.5kg were recruited.

The forefoot to rearfoot angle could not be accurately determined from the scans of the foam box impressions; therefore, these measures have been omitted from the analysis for both foam box techniques. ICC values falling below the predetermined quality threshold of .75 for excellent agreement have been bolded in tables 2 to 5.

**Caster Reliability**

The ICCs are presented along with volume matching percentages for intra- and intercaster reliability in tables 2 and 3, respec-
### Table 3: Intercaster Reliability

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Plaster Cast</th>
<th>Foam Box Sitting</th>
<th>Foam Box Walking</th>
<th>3D Scan (Relaxed Standing)</th>
<th>3D Scan (Corrected Standing)</th>
<th>3D Scan (Corrected Sitting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>0.88 (0.66–0.95)</td>
<td>0.93 (0.85–0.97)</td>
<td>0.88 (0.74–0.95)</td>
<td>0.92 (0.74–0.97)</td>
<td>0.94 (0.85 to 0.97)</td>
<td>0.92 (0.81 to 0.97)</td>
</tr>
<tr>
<td>Forefoot width</td>
<td>0.89 (0.75–0.95)</td>
<td>0.90 (0.59–0.97)</td>
<td>0.89 (0.69–0.96)</td>
<td>0.81 (0.59–0.92)</td>
<td>0.77 (0.52 to 0.90)</td>
<td>0.81 (0.60 to 0.92)</td>
</tr>
<tr>
<td>Heel width</td>
<td>0.86 (0.70–0.94)</td>
<td>0.91 (0.79–0.96)</td>
<td>0.88 (0.74–0.95)</td>
<td>0.93 (0.67–0.98)</td>
<td>0.93 (0.67 to 0.98)</td>
<td>0.91 (0.48 to 0.97)</td>
</tr>
<tr>
<td>Medial arch height</td>
<td>0.64 (0.32–0.83)*</td>
<td>0.41 (0.02–0.70)*</td>
<td>0.48 (0.07–0.75)*</td>
<td>0.73 (0.45–0.88)*</td>
<td>0.35 (–0.71 to 0.68)*</td>
<td>0.18 (–0.11 to 0.50)*</td>
</tr>
<tr>
<td>FF/RF angle</td>
<td>0.65 (0.33–0.84)*</td>
<td>NA</td>
<td>NA</td>
<td>0.83 (0.64–0.93)</td>
<td>0.77 (0.43 to 0.91)</td>
<td>0.75 (0.41 to 0.89)</td>
</tr>
<tr>
<td>Shape match, % (SD)</td>
<td>76.4 (11.5)</td>
<td>77.6 (6)</td>
<td>73.9 (10.8)</td>
<td>79.1 (8.8)</td>
<td>75.4 (9.2)</td>
<td>76.2 (8.2)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; FF/RF, forefoot to rearfoot; ICC(2,1), two-way random, single measures, absolute agreement intraclass correlation coefficient; NA, not applicable. *Values fall below the ICC quality value of 0.75.

### Table 4: Intra-CAD Operator Reliability

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Plaster Cast</th>
<th>Foam Box Sitting</th>
<th>Foam Box Walking</th>
<th>3D Scan (Relaxed Standing)</th>
<th>3D Scan (Corrected Standing)</th>
<th>3D Scan (Corrected Sitting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>0.88 (0.79–0.93)</td>
<td>0.89 (0.80–0.94)</td>
<td>0.96 (0.93–0.98)</td>
<td>0.85 (0.72–0.92)</td>
<td>0.93 (0.88–0.96)</td>
<td>0.99 (0.98–0.99)</td>
</tr>
<tr>
<td>Forefoot width</td>
<td>0.95 (0.90–0.97)</td>
<td>0.91 (0.79–0.95)</td>
<td>0.97 (0.94–0.98)</td>
<td>0.90 (0.82–0.94)</td>
<td>0.97 (0.94–0.98)</td>
<td>0.81 (0.69–0.90)</td>
</tr>
<tr>
<td>Heel width</td>
<td>0.97 (0.94–0.98)</td>
<td>0.91 (0.82–0.96)</td>
<td>0.98 (0.96–0.99)</td>
<td>0.79 (0.58–0.89)</td>
<td>0.88 (0.79–0.93)</td>
<td>0.92 (0.83–0.96)</td>
</tr>
<tr>
<td>Medial arch height</td>
<td>0.95 (0.90–0.97)</td>
<td>0.72 (0.52–0.84)</td>
<td>0.94 (0.89–0.97)</td>
<td>0.50 (0.24–0.69)</td>
<td>0.96 (0.92–0.98)</td>
<td>0.96 (0.93–0.98)</td>
</tr>
<tr>
<td>FF/RF angle</td>
<td>0.65 (0.44–0.79)</td>
<td>0.83 (0.70–0.90)</td>
<td>NA</td>
<td>NA</td>
<td>0.92 (0.85–0.95)</td>
<td>0.97 (0.95–0.98)</td>
</tr>
<tr>
<td>Shape match, % (SD)</td>
<td>87.1 (13.2)</td>
<td>67.7 (31.9)</td>
<td>89.4 (8.2)</td>
<td>68.4 (31.2)</td>
<td>88 (8.8)</td>
<td>69.9 (29.6)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; FF/RF, forefoot to rearfoot; ICC(2,1), two-way random, single measures, absolute agreement intraclass correlation coefficient; NA, not applicable. *CAD operator 1; †CAD operator 2; ‡Values fall below the ICC quality value of 0.75.
Effect of Method Used to Obtain Foot Shape

Results of the multiple linear regression analysis for arch height and forefoot to rearfoot angle are presented in Table 7. For medial arch height, differences ranging from 1.9 to 9.8 mm were found when compared against the plaster cast, with all the scanning methods resulting in a lower medial arch height. With the exception of 3D scanning (relaxed) versus 3D scanning (corrected sitting) (P = 0.527), 3D scanning (corrected standing) versus foam box (walking) (P = 0.055), and foam box (sitting) versus plaster casting (P = 0.119), medial arch height testing with analysis of variance followed by post hoc comparisons showed significant differences between all methods (P < 0.001 in all cases).

For forefoot to rearfoot angle, post hoc testing showed the 3D scan of the foot in a relaxed position to be significantly different from that obtained with all other tested methods (P < 0.01 in all cases), being 2.2° more everted than plaster casting. For other comparisons, P = 0.668 for 3D scanning (corrected standing) versus 3D scanning (corrected sitting); P = 0.793 for 3D scanning (corrected standing) versus plaster casting; and P = 0.997 for 3D scanning (corrected sitting) versus plaster casting.

CAD Operator Reliability

The ICCs for intra- and inter-CAD operator reliability are presented in Tables 4 and 5 along with volume matching percentages for each method. Smallest real differences are given in Table 6. Overall, all methods showed good intra- and inter-caster reliability for orthosis length, width at forefoot, and width at the heel. However, the intracaster medial arch height was highly variable, with all methods falling below the quality threshold for this measure, and forefoot to rearfoot angle reliability for plaster casting was below that of all the scanning methods for both casters. The volume match within casters was similar for all methods (<5% difference). Between-caster reliability for medial arch height was also low for all methods, along with forefoot to rearfoot angle for plaster casting. Volume matching varied between 71% (foam box walking) and 79% (3D scan relaxed standing).

DISCUSSION

Intracaster correlations were in line with those previously reported in the literature. Laughton et al.14 investigated the use of 4 methods including plaster casting, sitting foam impression, and a partial weight-bearing scan and found all intrarater ICCs for rearfoot and forefoot widths to be above 0.9. Forefoot to rearfoot angle and medial arch height ICCs were lower; however, higher values for the plaster cast forefoot to rearfoot angle were reported compared with those presented here. Similarly, Carroll et al.13 found intra- and inter-caster reliability values greater than 0.9 for forefoot width, rearfoot width, and cast length (equivalent to orthosis length) for plaster casting and non–weight-bearing 3D scan; however, the medial arch height...
reliability was higher from the 3D scan than the values presented here. It should be emphasized that the measurements used by these previous studies were of the foot parameters themselves rather than an orthosis designed against the scan, and this may explain the slightly lower reliability values. No operator blinding was reported in either of the previous studies, a factor that may have significantly influenced the results. The 3D scanning method used by Carroll13 was also slightly different from those used here, and so a direct comparison cannot be made.

The subtalar joint neutral technique employed in this study requires careful manipulation of the forefoot and rearfoot segments during casting. Variability clearly influences surface geometry and the forefoot to rearfoot measurement parameter, which was not reliable in this study. This may influence therapeutic effect such as pressure distribution, motion control, or muscle function. Surface geometry and alignment tolerances for custom-made FOs in terms of function, comfort, fit, and ultimately patient outcome have yet to be established.

The skilled craftsman may still have advantages for determining design features such as peak medial arch height. The ability to reproduce this parameter in the current study was poor for all methods of obtaining foot shape, and this is probably related to difficulties in defining the appropriate underlying anatomy. Palpating the tuberosity of the navicular is the most relevant surface landmark, but the highest point of the arch may be inferior to this and vary because of subcutaneous tissue, which is mobile and will change position according to the loaded state of the foot during casting. The use of more dynamic-type measurements may be a more appropriate method for defining orthosis design parameters because static measures may not accurately account for functional changes in the shape of the foot during gait.15

Previous work has focused on the reliability of foot scanning or casting by taking measurements from the 3D representation of the foot, as opposed to the actual device that is produced.13,14 This study has demonstrated that independent of the method used to obtain the foot shape, significant variability can occur at the CAD stage of producing an FO, and this should be considered an important factor in any assessment of different techniques for the design of CAD CAM FOs.

These results also suggest that using only basic foot scan and FO measurement parameters may fail to fully capture the variability in CAD FO design. Although the more general linear measurements taken from the device showed little dif-

### Table 6: Smallest Real Difference for Casters (mm)

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Plaster Cast</th>
<th>Foam Box Sitting</th>
<th>Foam Box Walking</th>
<th>3D Scan (Relaxed Standing)</th>
<th>3D Scan (Corrected Standing)</th>
<th>3D Scan (Corrected Sitting)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1*</td>
<td>2†</td>
<td>Inter‡</td>
<td>1 2</td>
<td>Inter</td>
<td>1 2</td>
</tr>
<tr>
<td>Length</td>
<td>4.22</td>
<td>5.16</td>
<td>2.91</td>
<td>4.1</td>
<td>5.59</td>
<td>1.99</td>
</tr>
<tr>
<td>Forefoot width</td>
<td>4.80</td>
<td>4.40</td>
<td>3.41</td>
<td>4.68</td>
<td>5.07</td>
<td>3.35</td>
</tr>
<tr>
<td>Heel width</td>
<td>3.71</td>
<td>5.04</td>
<td>3.40</td>
<td>3.89</td>
<td>3.26</td>
<td>2.54</td>
</tr>
<tr>
<td>Medial arch height</td>
<td>13.99</td>
<td>14.94</td>
<td>12.31</td>
<td>23.01</td>
<td>23.63</td>
<td>17.24</td>
</tr>
<tr>
<td>Forefoot to rearfoot angle</td>
<td>9.77</td>
<td>9.21</td>
<td>6.16</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Abbreviations: NA, not applicable.  
*CAD operator 1; †CAD operator 2; ‡Interoperator.

<table>
<thead>
<tr>
<th>Medial Arch Height</th>
<th>Unstandardized Coefficients</th>
<th>B</th>
<th>Std. Error</th>
<th>T</th>
<th>P</th>
<th>B†</th>
<th>Std. Error</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>34.024</td>
<td>.619</td>
<td>54.925</td>
<td>.000</td>
<td></td>
<td>2.175</td>
<td>.509</td>
<td>4.274</td>
<td>.000</td>
</tr>
<tr>
<td>Day</td>
<td>−0.259</td>
<td>.438</td>
<td>−0.591</td>
<td>.555</td>
<td></td>
<td>−0.425</td>
<td>.415</td>
<td>−1.022</td>
<td>.307</td>
</tr>
<tr>
<td>Caster</td>
<td>−1.087</td>
<td>.438</td>
<td>−2.482</td>
<td>.013</td>
<td></td>
<td>0.473</td>
<td>.415</td>
<td>1.139</td>
<td>.256</td>
</tr>
<tr>
<td>3D scan (relaxed standing)</td>
<td>−9.779</td>
<td>.759</td>
<td>−12.890</td>
<td>.000</td>
<td></td>
<td>2.227</td>
<td>.588</td>
<td>3.791</td>
<td>.000</td>
</tr>
<tr>
<td>3D scan (corrected standing)</td>
<td>−5.809</td>
<td>.759</td>
<td>−7.656</td>
<td>.000</td>
<td></td>
<td>−0.543</td>
<td>.588</td>
<td>−0.924</td>
<td>.356</td>
</tr>
<tr>
<td>3D scan (corrected sitting)</td>
<td>−8.478</td>
<td>.759</td>
<td>−11.174</td>
<td>.000</td>
<td></td>
<td>0.125</td>
<td>.588</td>
<td>0.213</td>
<td>.832</td>
</tr>
<tr>
<td>Foam box sitting</td>
<td>1.923</td>
<td>.759</td>
<td>2.534</td>
<td>.012</td>
<td></td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Foam box walking</td>
<td>−3.655</td>
<td>.759</td>
<td>−4.818</td>
<td>.000</td>
<td></td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Abbreviations: NA, not applicable; Std., standard.  
*The plaster cast method has been used as the referent for the models.  
†Positive values represent eversion of the foot compared with the plaster cast method.
ference between the CAD operators, the results for the volume matching demonstrated large variation in the reproducibility of the FO designs produced. A possible explanation for the higher reliability values found for CAD operator 1 compared with CAD operator 2, especially in terms of the volume matching, may be that operator 1 is a more regular and experienced user of the software package, suggesting that, beyond basic training, frequent usage may be an important factor for achieving consistent results from the software.

These results suggest that there are significant differences in FOs designed by using different methods and that investigation is warranted to determine whether these devices result in differences in biomechanical and clinically reported outcomes. The potential advantages of any one method need to be weighed against the efficacy of the device produced. Guldemond et al."10 previously showed that varying casting methods (foam box and plaster) resulted in FOs that produced differing biomechanical and clinically reported outcomes. Ki et al."17 performed a similar study comparing pressure relief from FOs produced by using CAD CAM against those from foam boxes and found significant differences between mid forefoot pressures. This has important implications for orthosis design, in particular for pressure offloading applications such as neuropathic foot ulceration. Further work is required for motion control and joint stabilization/realignment applications.

**Study Limitations**

There are 3 main limitations to this study. First, there are numerous variations on the methods used in this study that are used by podiatrists and orthotists around the world to obtain the foot shape, for example, in the positioning of the patient and the corrections applied to the foot. A pragmatic approach had to be taken here, and we feel that the methods used are a widely generalizable sample of those used today.

Second, the participants in this study were healthy individuals with mild, passively correctable structural impairments. Variability may be different in moderate-to-severely impaired feet, particularly those with underlying systemic disease such as rheumatoid arthritis. It is possible that in these more extreme cases, reliability at all stages could be affected. A number of more common, nonsymptomatic foot deformities were seen in the participant group, including hallux valgus, bunions, and flat foot deformity. Furthermore, caution should be applied in generalizing these results to groups with a rigid cavus foot type because a different prescription is commonly used to design devices for this foot type.18

Finally, the orthotic design software used offers a range of additional functions, allowing, for example, a range of modifications to be made to the scan image before the orthosis is designed. This would almost certainly introduce greater variability into the designs given the diverse prescription paradigms used by different clinics. However, the relatively straightforward design process employed in this study provides a conservative approach to determine how similar the orthosis designs are within and between operators using the same foot scan. If a reliable and consistent design cannot be obtained by using this approach, it is unlikely that a more complex approach, requiring modifications to the cast at the operator’s discretion, will produce more consistent results.

**CONCLUSIONS**

This study investigated 6 commonly used techniques for capturing foot shape, and none met all the criteria for excellent reproducibility. The peak arch height of the final device was particularly variable, with significant differences between most of the methods. The results for volume matching also suggest that taking simple linear or angular measures from the device may not fully capture the variability associated with the shape of the FO. Further variability is added to the overall process at the CAD stage of FO prescription; however, good to excellent reproducibility can be obtained for this stage, although this may be dependent on the experience of the individual using the software. Further work is required to determine whether the variability associated with the different stages of FO design that has been demonstrated here influences biomechanical and clinical outcomes in patient groups.

**References**


**Suppliers**

a. Easy-Foot-Scan; Baltic Orthoservice UAB, Taikos Avenue 131a, LT-51124 Kaunus, Lithuania.
b. Podo-Tech; A. Algeo Ltd, Sheridan House, Bridge Industrial Estate, Liverpool L24 HB, UK.
c. OrthoModel; Delcam PLC, Small Heath Business Park, Birmingham B10 OHJ, UK.
d. FastSCAN Cobra; Polhemus, Inc, 40 Hercules Dr, PO Box 560, Colchester, VT 05446.
e. Netfabb Studio; netfabb GmbH, Eichenbühl 10, 92331 Lupburg, Germany.