# 3D manufacturing: Printing a new nose

November 8 2012, by Penny Bailey

The suffering caused by the loss of a nose must be indescribable. In terms of function, a sense of smell is perhaps less important than the ability to see, hear and eat - and we can breathe through our mouth or nasal cavity. But somehow, a missing nose elicits a more profound sense of shock in other people than the sight of an eye patch.

It is, according to Jane Frances from Changing Faces, the most socially challenging of all facial disfigurements. She suggests this may be because our eyes, nose and mouth form what's called the 'communication triangle' of our face - the area where other people's gaze is focused.

Our nose is in the centre of that triangle, perhaps in part explaining why other people are so disturbed by the sight of a noseless face. I wonder if it is also because a nose stands proud of the face, so to cover the cavity with a patch can't mitigate the shock in the same way it can a missing or damaged eye: there's still a visceral sense that an essential structure of

the face is missing - 'standing out' by its absence.

It can only really be replaced by a similar structure - ideally, a surgically reconstructed nose. That may not be possible if the nose was removed because of cancer and the area needs to be monitored regularly, in which case a realistic-looking, comfortable prosthesis is the next best option.

For children whose faces are still growing, both options might be inappropriate. A reconstruction would require repeated surgeries to accommodate the changing facial tissues, and a prosthesis is also likely to require repeated surgical procedures to embed new attachments in the growing bone.

Jane cites an example of a boy who lost his nose after an infection when he was two: he couldn't have a prosthesis until he was fully grown because repeated surgery would damage the already fragile scar tissue surrounding his nasal cavity. Consequently, he went to ordinary mainstream primary and secondary schools in London, without a nose, until he was 18.

It's sad that it seems so inevitable, but she says that ostracism and teasing led him to become withdrawn, lonely and angry. "As a young adult, he has now had a surgical reconstruction. But that can't undo the distress he experienced throughout his education, which I am sure will have affected his capacity to achieve his potential," says Jane.

A prosthetic is also only an option for adults who have access to a prosthetic technician, or 'anaplastologist', with the skills and materials needed to make a realistic fake nose. They aren't available in parts of Africa and other countries where sometimes half a dozen dentists serve populations of millions and anaplastologists are unheard of. As a result, tens of thousands of people who have lost their noses because of cancer or injury have to face the world with a visible 'hole' in the centre of their

face every day.

Prosthetic noses made by Fripp Design and Research. Credit: Wellcome Images

In England, where we're fortunate enough to have dedicated oral maxillofacial centres with technicians skilled at building prosthetic noses, it's still an uncomfortable and difficult process that underscores the physical and emotional loss: the first stage of the process involves inserting plaster of Paris directly into the cavity to take an impression of the area.

From that model, the technician handcrafts a new nose out of a rubbery material called silicone polymer and hand-paints it to try to match the colour and texture of the recipient's skin. You might have to endure several uncomfortable fittings - and wait several weeks - before you end up with a nose that fits properly and blends invisibly into your face. And

if you don't live near one of the 18 oral maxillofacial centres in the UK, the fittings will involve a lot of travelling.

Then your new nose will only last six to nine months. Both the material and colour start to deteriorate with exposure to cosmetics (to disguise the 'join'), sweat, pollution, UV light and other environmental 'insults'. This means going back to the maxillofacial centre to get a new one, and - because each nose is handmade - the quality inevitably varies, so there's no guarantee it will be as good as the last one.

## The 21st century

No one needs that kind of discomfort on top of the emotional anguish people must feel when they lose their nose. At the University of Sheffield, a team of researchers exploring biomaterials and implants became convinced there must be a way of harnessing 21st-century digital 3D technologies to make the process easier and more comfortable for patients.

"We knew there had to be a better, more modern, way of making soft tissue prostheses but we weren't sure how it could be done," says Professor Ric van Noort.

It was already possible to take photographs in 3D, design objects in 3D on a computer and manufacture 3D objects from scratch by printing out layer after layer of powdered material, bonded by a resin. 3D printing - also known as 'additive manufacturing' - is perhaps the most striking outcome of the digital revolution, a radically different process to traditional manufacturing technologies, which tend to involve reducing blocks of material by chipping or drilling to create the desired object.

One step ahead of the game, dentists were already using 3D digital technology to make crowns and onlays to order in their surgeries. (I still

remember a feeling of awe when I watched my first crown being printed out in 2008.)

Ric and his colleagues wanted to use a similar process to replace the soft tissues of missing ears and noses. They approached Fripp Design and Research, a Sheffield-based industrial design company - and with funding from a number of sources (including a Translation Award from the Wellcome Trust), Fripp took up the gauntlet.

Creating fleshlike prostheses, as opposed to porcelain teeth or crowns, posed a unique set of challenges. The material used would have to be strong, flexible and biocompatible (unlikely to trigger a toxic or allergic reaction when inserted into human skin). The colour would have to match the patient's specific skin tone exactly, and the whole prosthesis would need to blend as invisibly as possible into the surrounding face.

## 3D printing

Three years on, Fripp Design and Research have come up with a reliable process that got the thumbs-up from their first client (who wishes to remain anonymous), who had her nose removed because of nasal cancer in 2002. She was used to the traditional, invasive method of 'impression-taking' with plaster of Paris and had written off the morning for it, so she was sceptical when she was told that all she needed to do was sit down and have her picture taken.

One shot later, using an array of 3D cameras positioned at different angles to take a 180° image of her face, and it was done. After separate photos were taken of her skin tone and colour with a 2D camera - the 3D system is expensive and needs calibrating every time it's used - she was free to take her (slightly less enthusiastic) husband shopping.

Next, the computer-aided design (CAD) software, designed for the

project by Fripp Design and Research, went to work, morphing the 2D and 3D images and ensuring that the contours, texture and skin tone matched their client's face exactly so the join between her new nose and the rest of her face would be almost invisible. Once that was done, they had a printable file of the new nose.

The team had tested several materials that were soft and strong enough to create a fleshlike nose, but had never been tested for biocompatibility in medical applications before. They identified a starch powder that fit the bill and put it in the printer's equivalent of a paper tray. The printer then printed out layer after layer of the powder, held together by an aqueous binder containing resin and coloured inks, which gradually became the new nose.

Once it had been printed out the nose was the right shape but very brittle, so there was one more stage to go. "The parts that come out of the printer are like pastry: very fragile and absorbent," says Tom Fripp, managing director of Fripp Design and Research. To soften and strengthen the printed nose, they soaked it with a very low viscosity, medical-grade silicone fluid.

Unfortunately, soaking the nose in silicone changes its colour. "If you're wearing a purple or red T-shirt and you spill put water on it, it goes a darker colour," says Julian Yates, a consultant at the University of Sheffield's Department of Oral and Maxillofacial Medicine and Surgery. "That's what happens with this process. When you infiltrate a coloured prosthesis with silicone - we call it curing - the colour changes."

To compensate for that colour shift, the team created a small computer programme that adjusts the colour of the image sent to the printer so the final product will match the patient's skin tone exactly once it has been soaked in silicone.

It might make colour matching more of a headache, but the curing process has another very beneficial effect: the printed nose is placed onto a small base to allow the silicone to infiltrate it. As it drains off, it naturally forms an extremely fine feathered edge that bonds seamlessly to the face.

Because the powder that the new nose is made of is less dense than silicone - and it contains a smaller proportion of silicone than traditional hand-crafted noses - it's also lighter in weight. Their client noticed instantly how comfortable and lightweight it felt and said she liked the way the feathered edge made it easier to blend into her face. Another benefit is that her 'product file' could be stored electronically, so future replacements can printed directly off at the push of a button without her having to travel back to the clinic again.

## Prosthetics for Africa

The next step is to further validate the system by testing it on other customers, before going through the necessary legal and commercial processes to start making prosthesis on a large scale. As well as making the process easier and 'lighter' for people in England and Europe, the team hope their product will bring relief to the thousands of people around the world who don't yet have access to any kind of prosthesis.

To that end, they've identified a rudimentary handheld scanner that will approximate the job of the 3D camera system for a fraction of the price. "It can be used in conjunction with any 2D digital camera to capture the geometry and skin tone," says Julian Yates.

"All we need is that 3D and 2D data to print out the new nose or ear here in the UK and courier it back to them. We could send it out with a wide feathered edge, so the person at the other end can trim that back down to the right width and then apply additional colouring or make-up."

Ultimately, the wider, more difficult and less tangible challenge of other people's understanding and reactions is still one that needs to be tackled if people with facial disfigurements are to live happier lives. As Jane from Changing Faces says: "Alongside excellent prosthetic technology, specialised psychosocial support is vital to enable everyone to become more comfortable and confident regarding their changed appearance.

"We also need to address attitudes around appearance and difference which are prevalent in wider society, so that everyone is more accepting of variation and difference."

It's a theme that was reflected in the recent 'Superhuman' exhibition held in Wellcome Collection to coincide with the London 2012 Games. Examining human attempts to improve our bodies throughout history, it raised questions about what a 'normal' body is and what constitutes bodily enhancement. One of the items on display was a 19th-century silver nose attached to spectacles for women who had lost their nose to syphilis - a poignant reminder of how fundamental a nose is to a face, even when it has no biological function.

Provided by Wellcome Trust