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- » Understanding 3D models
- » Looking at the 3D modeling process
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Chapter 1

Exploring 3D Design

In this chapter, you discover all things 3D so that you can understand the basic terminology and concepts of the 3D universe before you go rushing off to the world of Tinkercad.

What Is 3D Modeling?

3D is the abbreviation for 3-dimensional. In the world of *Computer Aided Design* (CAD), *3D modeling* (also known as three-dimensional modeling) is the process or workflow of developing a computer-based (mathematical) model of any surface of an object, regardless of whether it's inanimate (such as a gear wheel) or living (such as an animal or a human being).

3D modeling is done in three dimensions via specialized software and, in your case, Tinkercad. The end product is normally called a *3D model.* Someone who works with 3D models may often be referred to as a *3D artist.*

The 3D model has the advantage that it can be displayed on the computer screen as a two-dimensional image through a process called *3D rendering.* For example, these images are often the uber-cool pictures you see in an architect's slideshow of a new building or house he designed. They also may be used in a computer simulation of physical phenomena, such as virtual prototype testing to see whether the lighting makes a new product desirable to a given market.

The iPhone is a typical example where lighting is an important facet of the design to highlight all the lovely curves and bevels on the iPhone case. (Can you tell I'm an Apple fan?) The model can also be physically created using 3D printing devices, which is where Tinkercad comes into its own, with the ability to export 3D model files for 3D printing.

3D models may be created automatically or manually. The manual modeling process of preparing geometric data for 3D computer graphics is similar to plastic arts, such as sculpting. Now that does sound complicated, right? It's not. The Tinkercad interface simplifies the manual 3D workflow, allowing you, the Tinkercad user, to manually create your 3D designs and take them all the way to 3D printing.

TECHNICAL STUFF

Tinkercad is classed as *3D modeling software*, which is a class of 3D computer graphics software used to produce 3D models. Individual programs of this class are called *modeling applications* or *modelers*. Tinkercad is one of several 3D modeling applications or modelers that are provided by the San Francisco–based software company, Autodesk.

Figure 1-1 shows a typical example of 3D design.

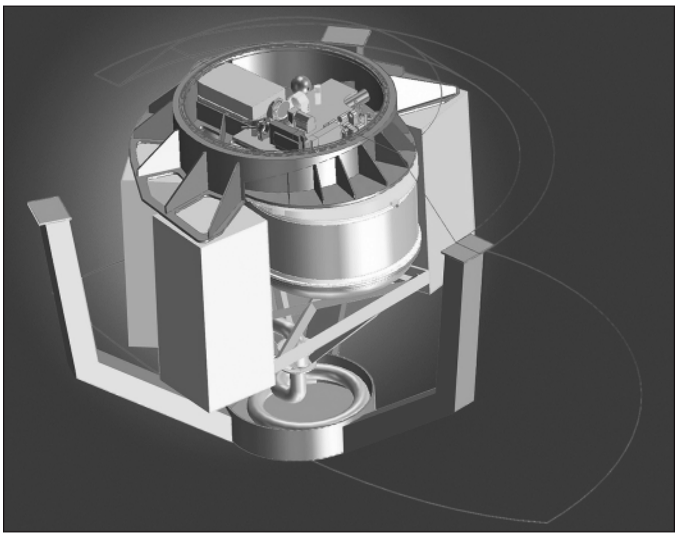

FIGURE 1-1: The ERIS high-resolution camera and spectrograph concept design for ESO's Very Large Telescope.

Credit: ESO/ERIS Phase A Team

3D MODELING IN THE REAL WORLD

As technology and computer hardware have moved forward and become much faster and much more capable, 3D models are now widely used anywhere in 3D graphics and CAD. Their use predates the widespread use of 3D graphics on personal computers nowadays, and many computer games used prerendered images of 3D models as sprites (not the soft drink) before computers could render them in real-time.

Today, 3D models are used in a diverse variety of fields:

- The **medical industry** uses detailed models of organs, which are created with multiple two-dimensional (2D) image slices from an MRI or CT scan.
- The **movie and television industry** uses them as characters and objects for animated and real-life motion pictures in film and television (think *Avatar, Star Wars,* and *Game of Thrones*).
- The **video game industry** uses them as assets for computer and video games. If you've used an Xbox, a PlayStation 4, or a Nintendo, you've used 3D assets in the games you've played, regardless of how cartoony or real-life they are.
- The **science industry sector** uses them as highly detailed models of chemical compounds, such as the human genome project.
- The **architecture and construction industry** uses them instead of traditional, physical architectural models to demonstrate proposed buildings and landscapes. However, some of those 3D models then become 3D printed models to show the new building or landscape in place in a city environment, for example.
- The **engineering community** uses them for the design of new devices, vehicles, and structures, as well as a host of other uses, such as nondestructive prototyping.
- In recent decades, the **earth science community** has started to construct 3D geological models as a standard practice. City modeling is now common practice within government departments in an effort to become more environmentally sustainable with the study of light and wind to create a more "green" world in which to live.

3D models can also be the basis for physical devices that are built with 3D printers or CNC machines.

Comparing 3D to 2D Methods

3D photorealistic effects achieved without wireframe modeling can be hard to distinguish when in their final form. Some of the software available has incredibly sophisticated filters that you can apply to 2D vector graphics or 2D raster graphics on transparent layers, making the finished image look remarkably realistic.

However, wireframe 3D modeling has several advantages over the 2D method:

- **Flexibility:** The ability to change angles or animate images with quicker rendering, because a realistic 3D model is already there to be used.
- **Easy rendering:** The automatic calculation and rendering is easier as the 3D modeler has built-in algorithms to render realistically rather than mentally visualizing or estimating the rendered image.
- **Accurate photorealism:** You have less chance of overdoing, misplacing, or forgetting to include any visual effects.

So, what disadvantages are there to 3D?

- **Software learning curve:** Learning 3D software can take longer as 3D modelers tend to be more sophisticated and have more "under the hood."
- **Difficulty achieving certain photorealistic effects:** You can achieve some photorealistic effects with special rendering filters included in the modeling software and specific to a 3D modeler. 3D artists sometimes use a combination of 3D modelers, following that up with 2D editing of the 2D computer-rendered images from the 3D model.

3D modeling makes sense if you're going to fabricate or manufacture your design. It provides a real-world model that can be viewed from any angle,3D printed in order for it to be visualized for real, and even submitted for nondestructive testing (such as the outer casing for a cell phone such as the iPhone, for example).

2D, on the other hand, is great for conceptual work. There is no need for full visualization because 2D is great for approximating what a model might look like with no need for a full 3D model to be created, thus saving on time, training, and costs.

Discovering Model Representation

A 3D model is represented either as a full solid or a shell of a solid. Imagine an old-fashioned wooden toy block as compared to a hollow Lego™ brick. Pretty much all 3D models fall into one of two categories:

- **Solid:** These models define the volume of the object or entity they represent (like a cube, for example). Solid models are often used for engineering and medical applications and are usually built with constructive solid geometry.

In this book, I show you how Tinkercad utilizes solids to make your life easier as you design.

- **Shell/boundary:** These models represent the surface of an object or entity. The boundary of the object is a bit like an eggshell and forms the object's shell, which is infinitesimally thin. Almost all visual models used in games and film are shell models, with surface properties applied.

Solid and shell modeling can create functionally identical objects, such as the Utah teapot, which is one of the most common models used in 3D graphics education (see Figure 1-2).

The differences between solid and shell modeling are the different methods in which they're created and edited in the various 3D modelers that are used, along with differing conventions of use in various fields.

Another difference is in the types of approximations between the model and reality, such as units of measurement and how the solids, shells, and boundaries are represented.

FIGURE 1-2: A modern rendering of the iconic Utah teapot model developed by Martin Newell (1975).

Credit: Dhatfield/CC BY-SA 3.0.

Looking at the Modeling Process

Imagine a big, infinite space, such as a galaxy in *Star Wars.* Your 3D models represent a physical object, such as a building, a gear cog, or even a nut or a bolt, by using a collection of points in that infinite 3D space (galaxy). You can connect these points using various geometric entities, such as triangles, lines, and curved surfaces.

Because the 3D model is formed by a collection of data (points and other information), you can create these 3D models by hand (manually), algorithmically (procedural modeling), or scanned (using 3D scanning methods).

You can further define their surfaces with *texture mapping,* which adds physical material attributes, such as brick, metal, or glass.

Creation of a 3D model

You can create a 3D model in one of three popular ways:

- Polygonal modeling
- Curve modeling
- Digital sculpting

These methods, which are described in the following sections, allow for very artistic exploration of the model with topology created over it after the models form and details have been sculpted. The new mesh will usually have the original high-res mesh information transferred into displacement data or normal map data if it's for a game engine. *Meshes* are nets of interconnected triangles.

Due to the accuracy and artistry digital sculpting provides, the 3D modelers used are often installed on tablets using highly accurate styli. Check out the 3D fantasy fish in Figure 1-3 for a typical example of a 3D model. It was modeled using organic surfaces.

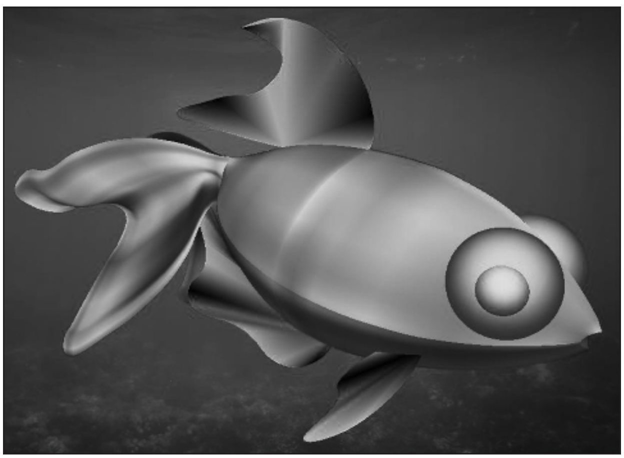

FIGURE 1-3: A 3D fantasy fish composed of organic surfaces generated using LAI4D.

Credit: Jahurtado/CC BY-SA 4.0.

Polygonal modeling

The points used to create a 3D model are called *vertices* and are connected by line segments to form a polygon mesh. (Imagine a 3D spider web, where it forms a 3D shape, and each line from each interconnecting point forms a 3D edge, and each of these edges forms the 3D model.)

Many 3D models created are developed as textured polygonal models because they're flexible and can be rendered extremely quickly.

The downside, however, is that polygons are planar and can only approximate curved surfaces using many polygons.

Figure 1-4 gives you a good idea of how polygonal modeling breaks down an object — in this case, a human head — into polygons to allow it to be modeled and rendered quickly.

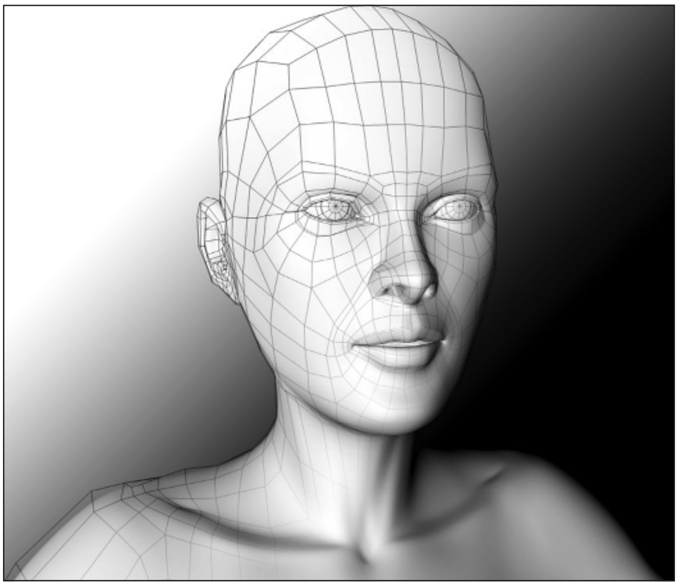

FIGURE 1-4: Polygonal modeling.

Credit: CC BY-SA 3.0.

Curve modeling

Using curve modeling, the 3D surfaces are defined by curves, influenced by weighted control points, which pull the curves in the appropriate direction.

The curve then follows the points (but sometimes will not interpolate them). If the weighting for a point is increased, it will pull the curve closer to that point.

Curve types include Non-Uniform Rational B-Spline (NURBS), splines, patches, and geometric primitives. While they all sound complicated, the 3D modeler, such as Tinkercad, will do all the math.

Digital sculpting

Digital sculpting is a new modeling method, which has become popular on current tablet devices that use the highly accurate styli now available.

There are currently three types of digital sculpting:

- **Displacement** is the most widely used among applications at this moment. Displacement uses a dense mesh model and stores locations for the vertex positions through use of a 32-bit image map.
- **Volumetric** is loosely based on *voxels* (an array of elements of volume that form a notional three-dimensional space) and has similar capabilities as displacement. However, it doesn't suffer from polygon stretching when a region doesn't have enough polygons to achieve a deformation.
- **Dynamic tessellation** is similar to voxels but divides the surface using triangulation to maintain a smooth surface and allow finer detail.

Exploring different modeling techniques

The modeling stage consists of shaping the individual objects that are used in the 3D scene. Numerous modeling techniques exist, including

- **Constructive solid geometry:** This is where you create a complex 3D surface or 3D object using Boolean to combine simpler 3D objects together.
- **Implicit surfaces:** An implicit model is formed by a continuous, volumetric model, where the volume of the model forms the 3D implicit surface, developed using numerous mathematical algorithms.
- **Subdivision surfaces:** In this modeling technique for making high-res models, a lower resolution cage model is subdivided by the modeling software for a smoother 3D surface.

The modeling is performed by means of a dedicated application, such as Autodesk 3ds Max or Maya, or a plug-in component, such as Lofter in 3ds Max.

Sometimes, no defined boundaries exist between the modeling techniques, and they are often used in conjunction with each other as part of the scene-creation process.

Often, complex materials, such as blowing sand, clouds, and liquid sprays, are modeled with particle systems and are a mass of 3D coordinates, which have either points, polygons, texture splats, or sprites assigned to them.

In the mathematical sense, 3D modeling has been around for a long time, but *virtual models*, where the real world is represented in 3D for you to see on your screen, really kicked in during the late ’90s:

- **Human models:** The first available application of human virtual models appeared in 1998 on the Lands’ End clothing website. The models used on the website were created by the company My Virtual Mode, Inc., and enabled users to create a model of themselves and try on 3D clothing. You can use many 3D modeling software applications, such as Poser, to create virtual human models.
- **3D clothing:** Software that simulates cloth and textiles has allowed artists and fashion designers to model dynamic 3D clothing in modelers, such as MarvelousDesigner, CLO3D, and Optitex. Dynamic 3D clothing is often used for virtual fashion catalogs, realistically clothing 3D characters in video games, 3D animated movies, and digital doubles in movies. These 3D modelers are also used for making clothes for avatars in virtual worlds, such as Second Life.

Figure 1-5 shows a dynamic 3D clothing model made in MarvelousDesigner.

FIGURE 1-5: 3D clothing model made in MarvelousDesigner.

Credit: CGElves/CC by SA 4.0.

Recognizing the 3D Model Market

Did you know that 3D models are, quite literally, everywhere? Many consumer products you now buy and use are 3D printed verbatim from their 3D models and used at work, in the home, and in numerous industries. The technology behind 3D is moving fast, and you'll find that 3D "stuff" is affecting design and the human interface in ways you never thought existed.

Here's an example for you. Remember those old mice you used to use on your old PC? You know the ones, right? They were a very basic shape with a ball inside that you needed to get out once a month to clean crumbs, food, and dust off the contacts. You remember? Need I say more? I am sure that the mouse in Figure 1-6 will jog your memory!

FIGURE 1-6: A typical 1980s Microsoft mouse. Check out those ergonomic curves!

Credit: PCWorld.

For one, new mice don't have that annoying ball inside anymore and use laser technology to work, but for two, they're designed so much better. They fit your hand both ergonomically and anthropometrically to alleviate things such as Repetitive Strain Injury (RSI). This transformation is due to the advent of 3D design, but also more importantly, 3D printing. Mouse manufacturers now use 3D prototypes developed by 3D design studios to test those ergonomic principles that alleviate RSI and other associated office-based injuries. (Bet you never knew the office was so dangerous, right?) The mouse in Figure 1-7 is similar to the mouse people now use every day for 3D modeling.

There are numerous uses for 3D models (way too many to mention here), but design software vendors, such as Autodesk, have realized that their software applications need to address this issue. The world has moved forward from just simple 3D designs in applications, such as AutoCAD. While AutoCAD is still a very relevant CAD application, Autodesk has continued to add to its toolbox of 3D CAD applications with products such as Inventor, Fusion 360, and, of course, Tinkercad.

3D models are now the norm. They're the benchmark for design. Computers are now powerful enough to manage large-scale 3D models easily. The Internet is now very powerful as well, with cable and fiber broadband Internet providing incredible speeds and bandwidth. The cloud is becoming all the more powerful, allowing complex design tasks to be done on the Internet remotely, taking away the need for large processing tasks on your computer on your desk.

These reasons are why Autodesk has invested so much time in Tinkercad. Being cloud-based, Tinkercad provides an entry-level 3D design product for everyone, processing your 3D designs quickly and easily in real-time, with no need for heavy local processing on your computer.

3D models in Tinkercad are easy, and this book shows you how easy it is and gets you out there into the 3D world, creating and even 3D printing your 3D models, just like those uber-cool mouse manufacturers do now with their new designs.

FIGURE 1-7: A Logitech MX Master 2S mouse. It sure looks cool, right?

Credit: Logitech Europe/CC by SA.

TECHNICAL STUFF

Cloud computing (the cloud) is a software and infrastructure model based on the Internet. It allows access to shared pools of data via an Internet interface in an Internet browser, such as Google Chrome or Microsoft Edge. Networks and servers can be managed this way, as can applications, such as Tinkercad. Cloud computing allows users to store and process data either in a private cloud or on a third-party cloud server located in a data center in a remote location. When using Tinkercad, your 3D designs are processed, calculated, and stored on a cloud-based remote server.

Exploring 3D Printing

3D printing is often known as additive manufacturing (AM), the additives often being powdered materials fed into a 3D printer to form a 3D printed solid model. These materials are layered under computer control to create the 3D solid.

A typical file format used is a STereoLithography file (STL). STL is one of the most common file types that 3D printers can read. 3D printing is different than traditional production processes where material is removed from machine stock, such as metal sheets. 3D printing (AM) builds a 3D solid object from a CAD model (often in a STL file format) by adding material layer by layer, using multiple passes of the printer head, in the same way you now print onto paper using inkjet technology.

Historically, the term *3D printing* refers to a chemical process that deposits a binding material onto a powder bed with inkjet printer heads layer by layer. However, 3D printing is now used in much more general terms and is the popular terminology used to describe a wide variety of additive manufacturing (AM) techniques. For the real techie nerds amongst you, the United States and global technical standards use the official term *additive manufacturing* (AM) to encompass all of the manufacturing techniques out there, and the documented standard ISO/ASTM52900-15 defines seven categories of AM processes within the standard document: binder jetting, directed energy deposition, material extrusion, material jetting, powder bed fusion, sheet lamination, and vat photopolymerization. Now, these all sound somewhat complex, and they are, and if you're really interested, check them out on Google and/or Wikipedia.

At a simpler level, you'll be pleased to know that if you design your 3D models on Tinkercad, you can output them as 3D physical models using the STL file format, which in turn can allow you to 3D print to the Autodesk 3D printer and use the Autodesk Spark platform, for example. Figure 1-8 shows you the new Autodesk 3D printer that has adopted the Spark platform for 3D printing.

FIGURE 1-8: The Autodesk 3D printer that adopts the Spark platform for 3D printing.

Using 3D Printed Models

Well, now that there is a process where the 3D conceptual design (inside your computer) can be made into something real (outside your computer, in the REAL world), it has revolutionized the world of design. Designers and manufacturers can now 3D print anything and everything they need to.

The following sections provide just a small overview of some of the uses of 3D printed models around the world right now.

Prosthetics

One of the more humanitarian and heartwarming uses of 3D printing is in the medical industry by way of 3D printing human prosthetics. Using nanotechnology for incredible accuracy for the fit to the human form, 3D-customized prosthetics that would normally cost in the region of $50,000 can now be replaced with their 3D printed equivalent, which will sometimes only cost in the region of $50.

This ability has led to a movement within companies, such as Autodesk, to work closely with individuals who need prosthetics and the companies that provide them, sharing the technology for the benefit of the person requiring a prosthetic.

An incredible organization called the Enable Community Foundation pairs volunteers in the e-NABLE community with designs and children needing prosthetic limbs, such as arms and hands, even giving the kids the choice of design and colors they want. In fact, a UK-based company called Open Bionics even offers low-cost, 3D printed hands with famous movie themes, such as Marvel's *Iron Man*, Disney's *Frozen*, and Disney's *Star Wars*, as shown in Figure 1-9. Open Bionics also offers free downloads of 3D designs that can be 3D printed, such as the Ada prosthetic hand shown in Figure 1-9.

FIGURE 1-9: The range of children's prosthetic hands available from UK-based company Open Bionics.

Credit: Open Bionics.

Rapid prototyping

Rapid prototyping is probably the most popular use of 3D printing. Manufacturers can now design and print on site, saving a lot of time and money on outsourcing this type (pardon the pun) of work to a third-party. 3D designers can then test and calculate whether their design fails and needs reworking much faster. 3D printing their design allows them to identify any design problems, fix them, and then reprint them.

In previous years, traditional prototyping was an expensive process, where (often) a full design was modeled, built, and then tested against specific project standards. This could take weeks, or even months, for more complex 3D models. The new rapid prototyping methodologies with the new, faster 3D printers allow companies to even 3D print in parallel, creating many variations on a theme so that they can compare each design to work out which one works best. This process is sometimes known as *iterative design.* This kind of rapid prototyping can be used in any industry, especially for nondestructive testing objects, such as eyeglasses, mobile phones, and even children's toys.

Education

3D printing is becoming extremely popular at all levels of education. It's not just being used for product design and engineering. 3D printing is also being used as an educational resource for the future. The world of 3D printing is growing rapidly, and schools, colleges, and universities are seeing that there will be a high demand for students with 3D printing and CAD skills. Figure 1-10 shows schoolchildren using a 3D printer in the classroom — a valuable resource for children learning technology and design in class.

Credit: Materialize.

FIGURE 1-10: Schoolchildren using a 3D printer in the classroom.

Education has to prepare the workforce for the skills needed in the future, and 3D printing is right up there. There is, however, still the need for education funding to ensure that students have full access to the 3D printing equipment, and that momentum needs to be maintained. 3Ders Autodesk works closely with many schools promoting Tinkercad as an entry-level application that gives the children access to 3D modeling and 3D printing. Figure 1-11 shows the Tinkercad team at work.

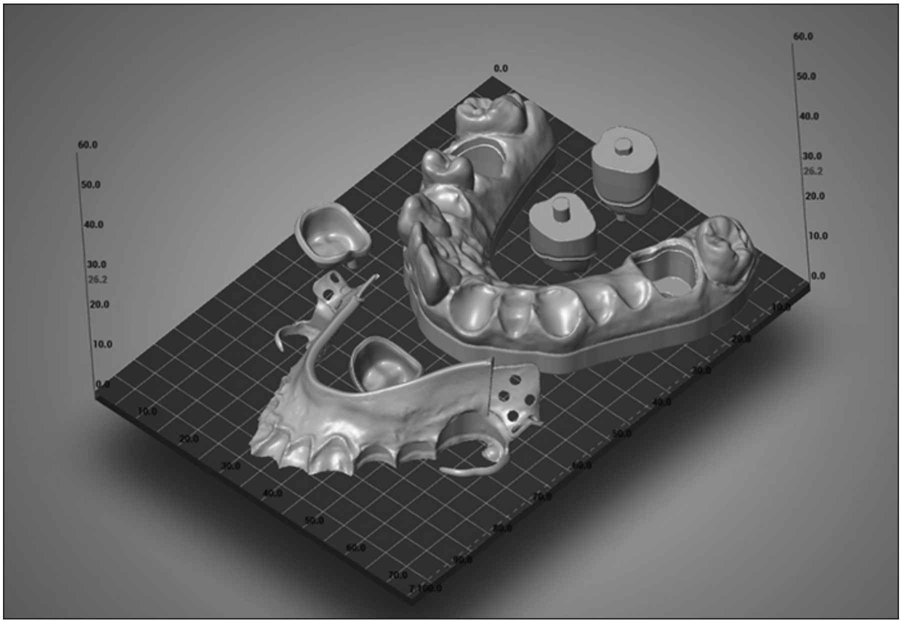

FIGURE 1-11: A nesting of partial dental framework, model, and crowns waiting to be 3D printed.

Credit: Dental Wings, Canada.

Low volume manufacturing

Many organizations and companies in the product design and manufacturing industries are moving from rapid prototyping to low volume manufacturing. There is often a need for only a small run on a specific part or product. If only, say, 50 copies of a part or product are needed for a low volume manufacturing run, it's likely to be much more cost-effective to have them 3D printed than shipped to a large-volume third-party manufacturer.

Bespoke manufacturing

Sometimes a bespoke or customized product or part may be needed. In manufacturing, it's often much less expensive to quickly 3D print a unique product or part like this as the materials can be obtained for the 3D printer and it can be individually designed and 3D printed in-house, instead of having to go to an external design company.

An example could be the production of a box with a client's logo embedded or embossed in it. This would be a great Tinkercad project!

Dentistry

I can bet that when you have been to your dentist, she has, at least once, taken an impression of your teeth to create a copy (sometimes known as a stone) to store for dental and legal reasons. On a macabre note, should you die in suspicious circumstances, dental records have been used for identification purposes. On a much brighter note, 3D printing is now becoming used as the norm in dentistry, allowing dentists to use a 3D dental scanner. This process captures a 3D image of your mouth, which means that the stones can be printed on demand, negating the need for the dentist to store hundreds of thousands of stones in a warehouse for many years.

Dental labs can now use 3D impressions of your teeth to create perfect fitting crowns, bridges, and implants. This ability saves on the time taken for these dental items to be made, reduces the risk of error, and saves the dental lab (and you) money. Figure 1-11 shows a partial dental framework, model, and crowns waiting to be 3D printed. The dentist, with appropriate 3D modeling training, can do this in-house for his patients, saving valuable time and money.

Using Tinkercad in 3D Modeling

Tinkercad is a cloud-based 3D modeler provided by one of the biggest design software companies in the world, Autodesk.

This cloud-based approach removes the need for local 3D model storage (no need for huge hard drives or servers), utilizing the cloud for both model storage and processing of the 3D model design as you work through your design, refining the model to the required look and feel.

Tinkercad is a great entry-level to 3D modeling, and with its ease of access (all you need is an Autodesk ID), it can be used by designers of all ages, from young children all the way up to advanced adult designers. It even has links in it that allow you to create 3D models for the online game Minecraft, and you can convert your models into Lego bricks, too!

While Tinkercad is a great entry-level modeler, you may want to consider a more sophisticated 3D application should you wish to develop and manufacture your designs on the factory floor. Tinkercad is great, but it is more suited to the hobbyist/maker space rather than the corporate production line methods needed to get a fully fledged design out to market.

Saying that, though, who knows? You may design the next latest and greatest in Tinkercad and then take it to the next level. You just never know!