THE EVOLVING USE OF COMPUTER-AIDED DRAFTING, DESIGN, AND MANUFACTURING IN ORTHODONTIA

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Abstract—Computer-aided drafting and design (CADD) is a computer-based program that improves the efficiency of product design and components both inside and outside of engineering. In recent years the use of CADD in dentistry, more commonly known as computer-aided dentistry, has become commonplace, allowing doctors and patients to individually design treatment with the result visible through computer-generated pictures of the mouth and teeth. To more efficiently treat patients, engineers and orthodontists create 3D-printed aligners using CADD.

In 1997, orthodontic treatment changed forever when Align Technology, Inc. introduced the now-popular Invisalign system to the world. Invisalign replaces traditional metal braces with a series of retainers that patients use, swapping each retainer for a new one every couple of weeks. Dentistry has taken a large step forward with the relatively recent introduction of CADD into its advancements. With the use of CADD in dentistry, such as Invisalign, patients can envision the end goal and dentists and orthodontists can better plan treatment with a 3D model of the mouth. The treatment is more timely, more comfortable, and more efficient than traditional metal braces.

Key Words—3D printing, ClinCheck Pro, Computer-aided dentistry, Computer-aided manufacturing, Invisalign, iTero Element Intraoral Scanner, Vacuum Form Machine

COMPUTER-AIDED DENTISTRY: WHERE ORTHODONTIA AND ENGINEERING INTERSECT

Computer-aided dentistry sounds like a strange phrase. It combines two topics that people would never normally associate together: computers and teeth. However counterintuitive it may sound, computer-aided dentistry is one of the fastest growing processes to enter the orthodontic and engineering fields. This technology specifically applies to the field of industrial engineering, where industrial engineers can apply knowledge of production and systems to create a sustainable product. Computer-aided dentistry utilizes computer-aided drafting and design (CADD) and computer-aided manufacturing (CAM). CADD allows engineers to efficiently design products and product components, including aligners and retainers. CAM allows engineers and orthodontists to treat patients more efficiently by manufacturing 3D-printed aligners, giving doctors the ability to individually design outcome-driven treatment through computer generated pictures of the mouth and teeth. It allows patients to have a more satisfactory, timely, comfortable, and efficient treatment that does not include uncomfortable metal brackets. The most prominent example of computer-aided dentistry is Invisalign, which replaces metal braces with a series of aligners that patients use, swapping each aligner for a new one every few weeks. Computer-aided dentistry's effects on the world of dentistry and engineering can be observed by looking at where Invisalign came from, how it is created and applied for patients, and how the industry is changing.

THE HISTORY OF CADD

CADD has been the driving force in the development of computer-aided dentistry from the past into the present. CADD uses computer technology in order to create and share designs [1]. The very beginnings of CADD started in 1957 when Patrick Hanratty developed a Program for Numerical Tooling Operations, or "PRONTO" [2]. This was the first computer numerical control, or CNC, programming system that could be used by the public and companies. Even though PRONTO was available for public use, the average person did not own a computer, let alone one that could run early CADD programs, so it was barely utilized. Due to these circumstances, it was not until the 1980's that CADD truly began to take off. The introduction of programs such as UNIX, Autodesk, and AutoCAD allowed CADD to be implemented in early computers [2]. Coupling these
matures with more readily accessible designing programs allowed the development of CADD, driving it into common use. Of the three aforementioned programs, AutoCAD had the largest impact on the industry. “It’s developers set out to deliver 80% of the functionality of the other CAD(D) programs of the day, for 20% of their cost...but it was still largely 2D” [2]. While AutoCAD implemented an incredibly effective program, it still lacked the powerful three-dimensional aspect that defines CADD today.

With the creation of ACIS and Parasolid, three-dimensional modeling was introduced into CADD and this problem was finally resolved [2]. This key aspect would allow for improvement in the design and manufacturing of products, as the user can apply multiple light sources and rotate the object, giving the ability to render designs from different angles [1]. However, it was not until the 1990’s, when SolidWorks was released, that the average computer could run CADD programs [2]. This resulted in the failure of many of the smaller developer companies, due to an inability to meet the market demand of universally used CADD programs. This led to an oligopoly in the CADD industry as the smaller companies were bought out mainly by the “big four” companies—Autodesk, Dassault Systemes, PTC, and Siemens PLM [2]. Having CADD in the hands of a select few bigger companies with larger teams working on its development allowed it to progress at a faster rate. Since CADD can be applied to a variety of projects and ideas, such as modeling, product analysis, and product management, it is a very powerful and successful tool. One of the fields that CADD has been applied to in recent years is orthodontia. By 2001, the application of CADD in dentistry had already resulted in the sales of one million 3D-printed aligners, and the trajectory of its success has only continued to rise [3].

**Dentistry and Engineering Working Together**

While not the most apparent engineering application, engineering’s footprint on the world of dentistry is prominent and inerasable. The most basic definition of engineering notes that an engineer is concerned with improving the efficiency of a process. Without a doubt, engineers have improved efficiency through the creation of Invisalign. Society has moved away from the world of traditional metal braces and into a world of dentistry filled with technological advancements. The initial creation of Invisalign was in 1997, and in the twenty short years since Invisalign’s birth, the technology has taken great strides. The ClinCheck Pro system has been created to allow doctors to modify tooth alignment with CADD. Physical impressions have been replaced with engineer-created photo scanners, which take better, more accurate pictures of the mouth. Pairing these photos with the latest in computer modification has increased the efficiency of the aligner design process. The benefits of computer-aided dentistry are vast—dentists and orthodontists plan better treatment via creation of a digital 3D model of the mouth, and along with patients, can more easily envision the end goal [3]. Engineers have been instrumental in the creation and development of Invisalign, and it is imperative that they continue to improve it for the future.

**THE DESIGN AND APPLICATION OF COMPUTER-AIDED DENTISTRY**

On the surface, traditional orthodontia and Invisalign implement similar processes. Both entail recommendation from a dentist and visits to an orthodontist, but upon closer examination, the similarities go no further. Where traditional braces require a physical impression, Invisalign utilizes a camera device. Traditional braces require monthly or sometimes even bi-weekly or weekly visits to the orthodontist’s office, whereas Invisalign gives patients multiple aligners at once and affords them more autonomy in completing their treatment. Traditional braces are obvious to the eye, whereas the presence of Invisalign is much more discreet. Both Invisalign and traditional braces are designed to achieve the same goal, but vast differences exist between the two systems. These contrasting systems are each suited to different patients and different circumstances.

If a patient is looking for a low maintenance treatment option with better quality of life, then Invisalign is superior. The aligners are removable, so patients have no restrictions on eating or drinking. In addition, the transparent appearance avoids the stigma of traditional metal braces. Invisalign aligners are more comfortable than traditional metal braces, and because the patient receives multiple aligners at once, the patient spends far less time in their doctor's office. Most exciting is the light at the end of the tunnel: Invisalign patients can view their end result on day one through the computer-aided design software used to virtually align the teeth [4]. With traditional metal braces, the patient will never see the end result until their braces are finally removed. Despite these clear advantages, the increased cost of Invisalign can be unattractive -- it averages at about $5,000 whereas traditional braces range anywhere from $1,800 to $5,500 [5]. However, the lesser cost of braces is paid for with time, as the average treatment time of traditional braces is two years compared to Invisalign’s average of twelve months [5].

**The Treatment and Manufacturing Process**

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Patient X has been evaluated, and Invisalign was chosen as their treatment plan. The first step in X’s treatment is the scanning phase, which utilizes a device such as the iTero Element Intraoral Scanner to take incredibly accurate pictures of their mouth [6]. The iTero scanner utilizes laser and optical techniques, which makes taking pictures easier and more precise [6]. Each iTero scanner unit consists of a wand connected to a touch-screen display for visualization [6]. As the wand is used to take pictures of the mouth, the scans appear on the screen and easily transfer into the CADD programs utilized by orthodontists [6]. In addition, the iTero software simulates treatment outcomes, so that the doctor and patient can see an approximation of the ideal alignment of X’s teeth [6]. Figure 1 shows the iTero scanner in use on a patient.

**FIGURE 1 [7]**
iTero Element Intraoral Scanner in Use

It is now time for Patient X’s orthodontist to get to work. Utilizing ClinCheck Pro, a CADD program, to align the digital model of the teeth, the doctor can visualize the treatment plan in real time [8]. This program allows the orthodontist to rotate individual teeth, view the mandibular and maxillary structures together and separately, and to add modifications for a better treatment [8]. Such modifications include the addition of anchor attachments to the teeth, which allow for more specific and precise targets for tooth movement, and precision cuts to the retainers, which keep the anchors in place [8]. In addition, when the upper and lower jaws are viewed on the screen, orthodontists have the ability to assess bite by visualizing which teeth make occlusal contact. This becomes useful in correcting bite problems such as overbites or underbites [8]. Most impressively, when one tooth is adjusted in the ClinCheck software, such as a slight rotation, the rest of the teeth in the 3D representation move according to how they would in the actual mouth [8]. Whilst making all of these adjustments in ClinCheck, orthodontists have the ability to make specific comments about the teeth and positioning, and the software generates its own comments to be read by technicians as the retainers are manufactured [8]. Before any adjustments are made in the software, an Invisalign Tooth Movement Assessment can be run. This assessment identifies how individual teeth need to be moved and the skill required to make each adjustment [9]. If the assessment marks a tooth blue in color, then it is slated to undergo a typical correction that has been historically made with success [9]. If the tooth is black, however, then this correction needs more advanced attention, such as the addition of the aforementioned anchors and precision cuts, which will assist in optimal positioning [9]. Aside from evaluating the difficulty of each movement, this assessment also identifies what type of adjustment is necessary, be it an extrusion, where the teeth are pulled to extend further from the gingiva, a simple rotation, or another manipulation [10]. Finally, this assessment quantitatively evaluates the degree of adjustment applied to each tooth. This assessment informs orthodontists of whether manual treatment should be implemented prior to making the adjustments, which allows for more personalized treatment for any given patient. The Invisalign Tooth Movement Assessment as run in ClinCheck is pictured in Figure 2 below.

**FIGURE 2 [8]**
Invisalign Tooth Movement Assessment with Adjustment Details

Once the orthodontist is satisfied with the extent of the adjustments made to the teeth, the ClinCheck treatment plan is sent to Align Technology, Invisalign’s parent company, who manufactures the aligners. The first step in the manufacturing process is three-dimensional printing the molds of the teeth through the
stages of treatment [11]. Each mold is then identified using radio-frequency identification, which organizes and accounts for the various molds and retainers throughout the extensive manufacturing process [11]. After each mold is created, the aligner material is vacuum thermoformed onto the molds. This process entails heating a sheet of plastic and then stretching it across a mold using a vacuum [12]. While still on the mold, the edges of the aligner are trimmed to fit in the patient's mouth, and a laser numerically identifies each aligner [11]. Then, the aligners are removed from the mold and polished using an automated milling process [11]. The aligners are packaged by an automated process, which by evaluating the laser identification of each aligner via radio-frequency technology, ensures that each patient receives their personalized aligners in the correct order without error [11]. The aligners are packaged into individual bags and the entire set is placed into a box, complete with identification labels, instructions, and information for the patient [11]. At each step in this process, the laser identification confirms that the correct retainers reach the correct patient in the correct order [11].

The material used to create the Invisalign aligners has also undergone updates and improvements. In the earlier years of Invisalign, typical thermoplastic orthodontic material was used to create the aligners. Soon after, however, product developers recognized the need for a more personalized material, with the goal of gaining more control over teeth movement [13]. From this, the SmartTrack material was born. When engineers discussed their priorities for a new material, the parameters included being wearable and attractive, providing better force on the teeth, and improved elasticity [13]. The aligners must be transparent, so that patients want to wear them [13]. Better force on the teeth entails a gentle, constant force, which is proven to be more effective biologically [13]. SmartTrack's stretching ability provides better conformity to each tooth and the surrounding area, and its elastic properties default to the programmed shape, consistently moving the teeth toward the end goal [13]. Because there is more contact between tooth and aligner, the tooth follows the programmed movement more closely, making for a more effective orthodontic process [14]. In addition, the material is more conducive to the presence of anchors and attachments than previous orthodontic material [14]. SmartTrack eases the treatment process for patient and doctor alike, as the aligners are easier to insert and remove than ever before. Compared to typical thermoplastic orthodontic material, SmartTrack makes has a more precise fit that provides a better, more comfortable treatment and patient experience [14]. The elasticity of SmartTrack versus standard material is shown in Figure 3.

After the SmartTrack aligners are manufactured and sent to X's orthodontist, Patient X will begin treatment. X receives instructions to wear their aligners for 20-22 hours each day, taking them out only for eating and drinking and cleaning teeth prior to putting aligners back in their mouth [5]. The average treatment time for an adult is twelve months, and X will schedule regular visits with their orthodontist approximately every four to six weeks [5]. Patient X receives instructions on when to swap out each retainer for a new one. Ideally, treatment will proceed as planned and the teeth will be moved to their optimal positions by the end of treatment. However, some cases require additional treatment after the first set of aligners has been exhausted. If X were in this situation, they would require new iTero scans, a new ClinCheck treatment plan, including the possible removal of current anchors or addition of new ones, and new SmartTrack aligners for the continuation of their Invisalign process [15]. This now proceeds identically to the first wave of treatment, and X will once again wear their aligners for 20-22 hours a day, still meeting with their orthodontist every four to six weeks to assess progress. In the time that it takes for the new set of aligners to be produced, X will be instructed to continue wearing the most recent aligner from the first treatment plan in more of a traditional “retainer” fashion of 10-12 hours daily, in order to prevent tooth movement while the new aligners are being manufactured [15].

Following completion of this process, Patient X is finally done with treatment, and their mouth is an accurate, real-life version of their optimal ClinCheck 3D model that was created by their orthodontist months ago.
X will likely be instructed to wear a retainer to prevent further movement of teeth [5]. The Invisalign company recommends the use of Vivera retainers, which have 30% stronger material than other popular retainer brands, keeping teeth in their optimal positions [5]. Vivera retainers are manufactured using the same technology that creates the SmartTrack Invisalign retainers, ensuring X a comfortable fit [5]. Each patient is different, so while some require the use of both top and bottom retainers, others are advised to use only one or the other, and the orthodontist will use their expertise to determine the best retainer plan for Patient X [5].

**EMBRACING THE FUTURE OF COMPUTER-AIDED DENTISTRY**

Computer-aided dentistry has come a long way since its inception and has benefitted countless doctors and patients throughout its development. There are countless stories of children, once self-conscious of their crooked, gapped teeth, who received aligners along with their orthodontic treatment a newfound confidence that would empower them for the rest of their life. Having a patient’s teeth straightened has become a common practice in today’s day and age, making it so important that there continues to be strides in the development of computer-aided dentistry. One such development can be seen in toothbrushes that implement electronics into a person’s everyday brushing ritual. Phillips’ new Sonicare toothbrush can be paired with a smartphone to include a three-dimensional map of the mouth [16]. Using Bluetooth technology, the brush sends data to the phone in real time, indicating when areas of the mouth are being neglected, and even when the toothbrush head requires replacement [16]. This toothbrush is bringing dental scanning technology of the mouth into patients’ homes. Another further development in the field of computer-aided dentistry that could be argued is the physical implementation of orthodontic three-dimensional printing. As of right now, the process for acquiring Invisalign involves scanning a patient’s teeth, drafting the model, waiting for weeks, and then finally receiving one’s aligners. The problem with this process lies within waiting weeks to receive the aligners and begin treatment. Cutting out the middleman and placing three-dimensional printers into individual orthodontists’ offices could easily solve this problem. This simple change would not only expedite the process, but it would also save the dentists and patients money.

Perhaps another middleman could be cut out of the process: the dentist. Future iterations of this technology could allow patients to design their own Invisalign aligners. Although this application is not yet possible for the average patient, it is worth considering for future use. The advanced CADD that engineers use has already been watered down into the ClinCheck program for a dentist’s use, which can analyze the user’s teeth and give them feedback for proceeding in their dental treatment [7]. If the ClinCheck program is accurate enough to communicate treatment areas and scenarios to the dentist, why not just tell the patients themselves? Overall, the ClinCheck program could be manageable for some patients to utilize on their own, however, problems could lie within program manipulation by irresponsible or uneducated consumers, creating precarious situations. In addition, more advanced treatment situations require additional forms of orthodontic practice as well as supervision that only a trained professional can provide. In addition, consumers would need to give their own time to develop an individual treatment plan. There is a fine line between the world of “do-it-yourself” self-improvement and treatment requiring a professional with years of education in a specialty. In computer-aided dentistry, the dentist is an indispensable part of the process, and therefore this line needs to be maintained.

**The Overlooked Importance of Dentists in Computer-Aided Dentistry**

“Do-it-yourself dentistry” has already been tried and tested by a struggling college student at the New Jersey Institute of Technology named Amos Dudley [17]. He is a three-dimensional artist who decided to print his own retainers since he had already gone through traditional orthodontic treatment early in his life. Because he had a three-dimensional printer, molding clay, and scanners available to him, he was tempted to try computer-aided dentistry himself, and succeeded. However, Dudley himself was quoted as saying, “I’ve heard from a few orthodontists and orthodontic technicians that I basically replicated the commercial process pretty closely...but I’d advise against making your own aligners” [17]. The process included ordering molding clay online, producing a casting, scanning the casting, 3D printing the model, and then using a vacuum form machine to shape the plastic aligners using the model. Although it has been said that Dudley copied the process closely, it took a lot of time, resources, and effort - and it was not nearly as well done as a professional dentist’s work.

Professionals had a multitude of comments to make on Dudley’s “do-it-yourself” process. Brent Larson, a practicing orthodontist and professor at the University of Minnesota School of Dentistry, was quoted saying that, “...when looking at the images of the DIYer’s teeth, there are specific areas of tooth wear visible that indicate unbalanced function and possible nighttime grinding.” [17]. Although Dudley’s procedure included equipment far above what the American public could expect to obtain, it is still a cautionary tale that professionals are
necessary for optimally effective and safe orthodontic treatment.

The Overlooked Importance of Engineers in Computer-Aided Dentistry

Dentistry has taken a large step forward with the relatively recent introduction of CADD into its advancements. Computer-aided dentistry is a unique innovation that can continue to be improved for years to come. As long as researchers and doctors continue making new medical and dental discoveries, new improvements to computer-aided dentistry will arise and the opportunities will remain vast. However, the average dentist does not have the specialized knowledge to develop technological advancements, and that is where an engineer comes into play. Invisalign itself was not created by a dentist or an orthodontist, but rather by a graduate business student with undergraduate majors in computer science and economics as well as knowledge of CADD and CAM. This student also happened to be an adult orthodontics patient, and after analyzing the effectiveness of his own treatment, Invisalign was born. Currently, Invisalign is engineering many improvements to its systems. The iTero scanning system is constantly being improved for better, more accurate pictures while also maintaining its ease of use [7]. The most recent Invisalign update, Invisalign G7, was released in October of 2016, and introduced more frequent, weekly aligner changes. G7 allows for more control over tooth movement and root control, making it more likely to achieve the desired outcome [18]. Along with G7, ClinCheck Pro 5.0 was released, which incorporates the G7 improvements along with an easier user interface for the CADD software [18].

At its core, computer-aided dentistry is engineering. It consistently improves a process for the public good. It takes into account the desires and dreams of dentists and orthodontists, making them a reality. It improves the patient experience by optimizing ease of use and comfort. Computer-aided dentistry is cutting-edge dentistry, and it would be lost and inexistente without engineering.

Why Computer-Aided Dentistry has the Public Good in Mind

One of an engineer’s most important purposes is to consider the welfare of all parties, something that the Invisalign system has accomplished [19]. Although some may say that engineers have no place in the field of dentistry, they have brought indelible improvements to the field. Industrial engineers add a flair of creativity to computer-aided dentistry that other professionals cannot, and they then use that creativity to refine Invisalign [20]. Invisalign as a product improves the quality of life for countless orthodontic patients, and gives consumers more options than just metal braces. As long as engineers and healthcare professionals continue to work together, new technologies will elevate patient care, products, and results.

One modern example of a company streamlining the Invisalign process is Smile Direct Club. This company’s goal, to further improve the quality of a consumer’s Invisalign experience, not only lowers the price roughly seventy percent to about $2,000, but also allows patients the option of receiving treatment at home. Smile Direct Club’s process begins by sending customers at-home impression kits to mold 3D models of their mouths [21]. Upon completion, patients return these molds to the company [21]. Using this model, Smile Direct Club then works with dentists to have aligners created for the recipient. The process stays at home, as Smile Direct Club sends customers their aligners, in addition to whitening gel, in the mail each month, so that the alignment process is slow and painless [21]. Once the treatment is complete, patients receive a pair of retainers to maintain their newly straightened smile forever [21]. Although treatment is primarily completed at home, the consumer is required by the company to consult with their orthodontist before receiving their retainers [21]. Smile Direct Club also allows consumers to receive their monthly treatments at a dentist’s office, but the mailing option provides a more convenient option to the customer. However, the weeks that pass while waiting for an aligner to arrive from the manufacturer still lengthen this process. It would be more convenient for the customer to visit their local orthodontist and receive their first aligners the same day as their impression or scans are taken. Of course, in order to expedite this process, the aforementioned three-dimensional printers in the dentist’s office become necessary. Computer-aided dentistry has made major strides in recent years and has great potential for the future.

Invisalign can improve not only the public good, but also the good of our planet. If an engineer’s products are not sustainable then they can possibly do more harm than good. One sustainability assessment that can be applied to Invisalign aligners is their choice and usage of materials. By ensuring that sufficient materials remain for future use and that the product’s environmental footprint is minimized, Invisalign retainers can be classified as sustainable or unsustainable. Invisalign is made from medical grade plastic called polyurethane, or more specifically, methylene diphenyl diisocyanate and 1.6-hexanediol [22]. Figure 4 shows a table of various polymers and their biodegradability with respect to time in vivo. Polyurethane is considered to be biodegradable, as it is 78% weaker after 8 months in vivo and completely disintegrated after 16 months. Thanks to this property,
patients and doctors utilizing Invisalign do not have to worry about the future effects of retainer waste on the environment.

<table>
<thead>
<tr>
<th>Material</th>
<th>Months in vivo</th>
<th>Tensile strength loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermoplastic polyurethane</td>
<td>8</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Disintegrated</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>17</td>
<td>44</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>17</td>
<td>36</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>17</td>
<td>24</td>
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<tr>
<td>Acrylonitrile</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>24</td>
<td>11.5</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>Silicate</td>
<td>17</td>
<td>2.0</td>
</tr>
<tr>
<td>Mylar</td>
<td>17</td>
<td>0</td>
</tr>
</tbody>
</table>

**FIGURE 4 [23]**

Biodegradability of Various Polymers

Traditional braces, however, do not have the sustainability of Invisalign. Braces utilize a variety of materials with varying levels of sustainability, such as rubber bands, metal archwires, and the ceramic concrete used to adhere the braces to the mouth, and more. Allergies to the metals and ceramics can be a major concern, as well as a large roadblock to treatment. In addition, once the metal archwires are removed from the mouth, no clear path exists for the materials. Some experts suggest sterilizing the metal and reusing it, but this is not commonly done due to patients' negative perceptions of “recycled” braces.

In any healthcare field, sustainability can be analyzed with respect to advancements being made and new information being researched so as to improve patient quality of life. Each day, doctors, researchers, and engineers gain new knowledge of the human body that, allowing them to refine their approaches toward patient treatment. Just as the healthcare field is continuously evolving, Invisalign is also constantly improving. Engineers and orthodontists will steadily be working to adjust Invisalign according to the technological advances in medicine. Thanks to this, Invisalign is one aspect of healthcare that will always have new and innovative discoveries and the need for engineers to make them.

**TOMORROW’S SMILES, TODAY**

Computer-aided dentistry is CADD and engineering applied to orthodontia through the groundbreaking technology of computer-manufactured aligners and retainers for consumer use. Invisalign in particular has shaped the lives and straightened the teeth of millions of people thanks to the work of innovative engineers and companies striving to provide the best for their customers. This innovation is forged in the fiery pits of CADD, modeled, and then sculpted out of the framework of a three-dimensional printer like a statue out of marble. The masterpiece is finally completed when the unique mold is coated in plastic, creating custom-made aligners for each and every patient. It has all evolved from the beginnings of CADD, as well as a need for a superior product to traditional metal braces, a need that was fulfilled by dentists working together with engineers to improve patient quality of life. Computer-aided dentistry is a transformation that will continue to improve itself and the smiles of the people it touches.

**SOURCES**

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ADDITIONAL SOURCES