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Digital Dentistry & the Full-Arch Prosthesis

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DIGITAL DENTISTRY

Digital dentistry can be defined as any dental technology or device that incorporates digital or computer controlled components in contrast to that of mechanical or electrical alone.[1] Digital technology in dentistry, such as computers in the operatories, digital radiographs, lasers, intraoral cameras, Cone Beam Computed Tomography (CBCT), Computer Aided Design/Computer Aided Manufacture (CAD/CAM), and Additive Manufacturing (AM or 3D printing) has been around for decades, but only until recently has digital technology been applicable to the planning, design ***and*** fabrication of full-arch implant supported prostheses.

When considering the full-arch implant supported prosthesis, four types come to mind: the screw-retained Hybrid Prosthesis, the Cementable PFM Prosthesis, the CAD/CAM Hybrid Prosthesis, and the CAD/CAM Zirconia Prosthesis. (Fig 1)

THE HYBRID PROSTHESIS

A hybrid prosthesis, by definition, is composed of different elements or types of materials. Generally, we understand a hybrid prosthesis as one in which the substructure is made of noble metal. The substructure is either waxed and cast, then covered by acrylic denture teeth and acrylic gingiva. This prosthesis is then screwed onto the dental implants. The hybrid prosthesis (Fig 1a) can be supported by a varying number of dental implants, usually four or more, depending upon several host conditions such and arch width, biting force, bone density, etc...

From a patient's perspective, the advantage of the hybrid prosthesis is that it is "better" than edentulism and "better" than a traditional denture because it is fixed in placed. No movement, no wobble, no pressure on the gingiva, and no removing it at bedtime. Fixation provides convenience and comfort.

From the dentist's perspective, a major advantage of the hybrid prosthesis is that it can be removed for servicing. Furthermore, the hybrid prosthesis can accommodate tilted and axially placed implants, common to the irregular anatomy of a resorbed alveolar ridge.[2]

Other appealing features of the hybrid prosthesis is that it provides lip support, it is less expensive to fabricate than the other prostheses available, and it can be highly esthetic.

Four Types of Full Arch, Implant Supported Prostheses

Fig 1a: Hybrid Prosthesis. *(Photo from the internet)*

Fig 1b: Cementable PFM Prosthesis. *(Courtesy of Dr. David Forlano and ceramist Thomas Yovino, Yovino Dental Studio, East Setauket, NY)*

Fig 1c: CAD/CAM Hybrid Prosthesis. *(Photo from Straumann Cares)*

Another feature of the hybrid can be a double-edged sword. Because the occlusal surfaces are made of resilient acrylic, the stress of occlusal forces on the implants, and on the crestal bone, is reduced.[3] This may seem appealing until one considers that this stress is borne by the acrylic and results in the acrylic breaking.[4] (Fig 2)

Fig 2: Hybrid prostheses have become less popular due to frequent breaks.

In fact, the literature reports replacement of denture teeth due to wear or fracture as the most common prosthetic complication of the hybrid.[5] So, in essence, the weak link of the hybrid prosthesis is in its beauty, namely, the plastic.

Other disadvantages[6] of the hybrid prosthesis revolve around the porosity of the acrylic. It attracts plaque and can stain. Also, the screw holes can be unaesthetic, and food impaction can occur between the prosthesis and the soft tissue. Speech problems or difficulties in dealing with hygiene are also reported in the literature.[7]

THE CEMENTABLE PFM PROSTHESIS

In an effort to resolve the problems with the plastic of the hybrid prosthesis, the Cementable PFM Prosthesis came to the rescue. (Fig 1b) Like a conventional fixed porcelain fused to metal roundhouse bridge that is cemented onto natural teeth, the full-arch Cementable PFM Prosthesis is cemented onto the implant abutments. Angulation of the implants is corrected with custom implant abutments to achieve parallelism and a path of insertion for the prosthesis. The abutments themselves can be waxed and cast, or milled using CAD/CAM technology.

Advantages of the full-arch Cementable PFM Prosthesis include less wear and breakage of the prosthetic teeth when compared to the hybrid prosthesis, the cement can take up minor casting errors, and there are no screw holes to cover.

One major disadvantage is retrievability. These prostheses are not so easy to remove when you want to remove them. On the other hand, when you want them to stay, retention seems to be a problem. Another disadvantage is that porcelain chips are a problem to repair. Also, there may be problems if only a part of the prosthesis loosens or abutment screws loosen. Furthermore, they are costly and time consuming to manufacter.[8]

Above and beyond these aforementioned disadvantages, the main current concern of the full-arch Cementable PFM Prosthesis, and with any cement retained implant restoration, is Residual Excess Cement (REC). Research shows that REC is associated with peri-implant disease in the majority of implants and a major cause of implant failure.[9]

Fig 3: The visual excess cement is not the concern. It is the Residual Excess Cement, that has flowed under the soft tissue as evidenced by the blanching, and onto the bone-implant interface, that is the concern and cause of implant failure.

Fig 1d: Zirconia Prosthesis. *(Photo courtesy of Michael Tischler DDS, Tischler Dental Lab)*

Interestingly enough, these failures seem to occur, on average, two years after restoration.[10] Any mass of foreign material adjacent to an implant could affect implant survival.

By arbitrarily lining an implant prosthesis with cement and inserting it onto an abutment until visual excess cement is extruded around the margins (Fig 3) is certainly a recipe for implant failure.[11,12,13] Excess cement is sure to seep subgingivally. Remember, "subgingivally" around an implant can mean in direct contact with the bone because there is no fiber attachment at the crest. Removal of REC around dental implants is very difficult.[14] Access to the subgingival areas with scalers and currettes is sometimes impossible because of the steep emergence profile. Even if one can access the REC, removing it from micro pores of the textured implant surface and threads is impossible with hand instruments and requires rotary instrumentation after dismantling and removal of the prosthesis.

THE CAD/CAM HYBRID PROSTHESIS

Further evolution of the full-arch implant supported fixed prosthesis brings us to a design that eliminates the cement by returning us to the screw retention of the hybrid prosthesis, but replacing the weak link of having plastic teeth with a more durable material, namely, porcelain. This prosthesis is what I call the CAD/CAM Hybrid. (Fig 1c)

The CAD/CAM Hybrid is composed of a screw-retained substructure made of either titanium or cobalt chromium, manufactured by CAD/CAM technology. Then, feldspathic porcelain is layered onto this substructure.

Examples of the CAD/CAM Hybrid include The Manhattan Bridge™ and the Gibraltar Bridge™. Both names are trademarked by Marotta Dental Studio, Inc, a dental laboratory located in Farmingdale, NY.

The substructure of the Manhattan Bridge™ is milled out of cobalt chromium, where as the substructure of the Gibraltar Bridge™ is milled out of titanium. Both types of substructures are manufactured by a only few facilities (Straumann Cares, Panthera Dental, Atlantis Isus and CMC Technology Center from Schein). Since the substructure is milled from a solid piece of metal, casting errors and distortion are eliminated. (Fig 4)

Steve Pigliacelli CDT MDT, Vice President and Director of Education at Marotta Dental Studio, Inc reports inherent difficulties with baking porcelain to titanium and seems to prefer the cobalt chromium. He states, "Cobalt chromium may have gotten a bad reputation over the years because of the inherent characteristics of non-precious metal. However, one must realize that titanium is also a non-precious alloy and we have been using that for years. Modern CoCh does not contain the harmful elements such as nickel and beryllium. The CoCh is easier to work with, can be sectioned and welded, and can have regular porcelain application to it without fear of incompatible oxide layers and highly technique sensitive procedures".[15]

Fig 4a: CAD/CAM technology milling titanium.

Fig 4b: Example of screw retained, milled CAD/CAM substructures.

Fig 4c: CAD/CAM Cobalt Chromium substructure ready for porcelain layering.

THE CAD/CAM ZIRCONIA PROSTHESIS

Continuing the evolutionary path of the full-arch fixed implant supported prosthesis comes the Zirconia Prosthesis. (Fig 1d)

This prosthesis is screw retained, so it eliminates the detrimental effects of Residual Excess Cement. Milled, stained, sintered and fired from a solid puck of zirconia, it is monolithic (Fig 5b). There is no layering of porcelain. Because this prosthesis has no layers of different materials, it has a leg up on all of the aforementioned prostheses. The zirconia prosthesis eliminates the use of plastic teeth and acrylic flanges. Being monolithic with a high flexural strength, the Zirconia Prosthesis is free from chipping.[16]

Another advantage of the Zirconia Prosthesis is that it is CAD/CAM milled so there is no casting distortion. Furthermore, it is fully customizable with regards to tooth size, occlusion and color. It is retrievable by the dentist. In fact, the screw access holes are strong and esthetic. It doesn't attract plaque like acrylic, requires less prosthetic space than the hybrids, and is resilient to staining and wear. Furthermore, most laboratories offer warrantees on these prostheses and in the rare case of needing a replacement, a new impression is not required. Rather, the click of a button to re-mill from the stored file is all it takes.

Two of the popular full-arch zirconia prostheses are the BruxZir from Glidewell Laboratory and the Prettau Bridge from Tischler Dental Laboratory. (Fig 1d)

Fig 5a: PMMA provisional prosthesis used during the full-arch zirconia prosthetic process.

Fig 5b: A solid block or puck of zirconia is the substrate for the milling procedure.

Glidewell Laboratory makes the following claims in its advertisement: "Constructed from 100 percent BruxZir Solid Zirconia, this full -arch restoration dramatically improves speech and chewing function and attaches to implants via titanium connections. BruxZir Solid Zirconia offers superior fracture toughness and exhibits flexural strength up to 1,465 MPa, making it ideal for enduring the functional stresses that dentures must withstand. BruxZir Solid Zirconia is biocompatible and lifelike, exhibiting remarkable translucency and color similar to natural dentition. State-of-the-art CAD/CAM technology is employed to achieve a precise fit and a predictable result. Strong, hygienic and affordably priced, the BruxZir Solid Zirconia Full-Arch Implant Prosthesis offers exceptional resistance to the chips, fractures and stains that can compromise acrylic dentures."[17]

The Prettau Bridge, made from Zirkonzahn's proprietary zirconia at Tischler Dental Laboratory in Woodstock, NY is similar to the BruxZir prosthesis from Glidewell.

Dr. Michael Tischler, owner of Tischler Dental Laboratory and one of Dentistry Today's Top 100 Educators, reports a prosthetic success rate of 100% with over 200 Prettau arches restored and in function for 1 -5 years, between 2012 and 2017 years.[18] Dr. Tischler combines the prosthetic advantages of a zirconia prosthesis with a specific surgical protocol. His protocol on the surgical placement of the implants allows for 1st molar occlusion without dependence on sinus grafting or ridge augmentations posterior to the mental foramen. [19]

His surgical procedure calls for 5-6 implants placed in the maxilla, between the mesial borders of the maxillary sinuses. In the mandible, a similar protocol calls for 5 implants spaced equidistant between the mental foramen. Utilizing the mesial of the maxillary sinuses in the maxilla and the mental foramina in the mandible as his anatomical landmarks, he describes placing all of the implants "between the goal posts", with the distal most implant on each side angled 15-20 degrees in order to increase the A-P spread. Avoiding sinus lifts and ridge augmentations is an advantage with Dr. Tischler's protocol, as total treatment time is significantly reduced. Furthermore, eliminating the need to place implants above the inferior alveolar nerve has the obvious advantage of reducing the risk of paresthesia.

When searching for disadvantages of the full arch zirconia prosthesis, there aren't many to be found. One can propose that this procedure requires a CAD/CAM capable laboratory. However, as more laboratories continue to add CAD/CAM technology to their armamentarium, this disadvantage is waning. One may also question the weight of the prosthesis comparable to the weight of an average CAD/CAM Hybrid or Cementable PFM respectively, but there are no reports in the literature. Anecdotally, Tischler reports no issues with the weight.

Some reports in the literature state that zirconia may cause excessive wear to the opposing dentition or prosthesis. However, some studies actually report less opposing tooth wear with zirconia than with feldspathic porcelain. [20]

Another concern of using zirconia is that it can not be sectioned and welded in the event of a seating problem. Cast alloys and titanium can be welded. This disadvantage is overcome by utilizing verification jigs and delivering a poly methyl methacrylate (PMMA) prototype of the final prosthesis, verifying not only the integrity of the fit, but the esthetics as well. (Fig 5a)

Tischler objectively states that the Prettau bridge supercedes the other full-arch prostheses because it is "milled, not cast, retrievable, it splints the implants, it is hygienic, it is esthetic, the screw access holes are strong and it can offer 1st molar occlusion without grafting."

When designing a CAD/CAM Zirconia prosthesis, emphasis is placed on pre-operative planning, both surgically and prosthetically. Surgical planning is beyond the scope of this article.

Prosthetic planning includes an accurate measurement of the available vertical restorative space. Glidewell Laboratory requires a minimum of 10mm of restorative space for their BruxZir prosthesis, while Tischler Dental Laboratory requires 12mm of vertical restorative space. When measuring the restorative space in the posterior, the restorative space is measured from the top of the implant to the occlusal surface of the planned prosthetic tooth. When measuring the restorative space in the anterior region, measurement is made from the top of the implant to the cingulum of the planned prosthetic tooth. This is for structural strength of the material.

CASE REPORT

DIAGNOSIS & PLAN

A 71 year old presented with chief complaint, "I can't wear my lower denture. I was told I was not a candidate for dental implants". Review of the medical history revealed no significant findings. Diagnostic records were taken (Fig 6) and evaluated to reveal full edentulism, ill fitting dentures with advanced atrophy of the alveolar ridges with an

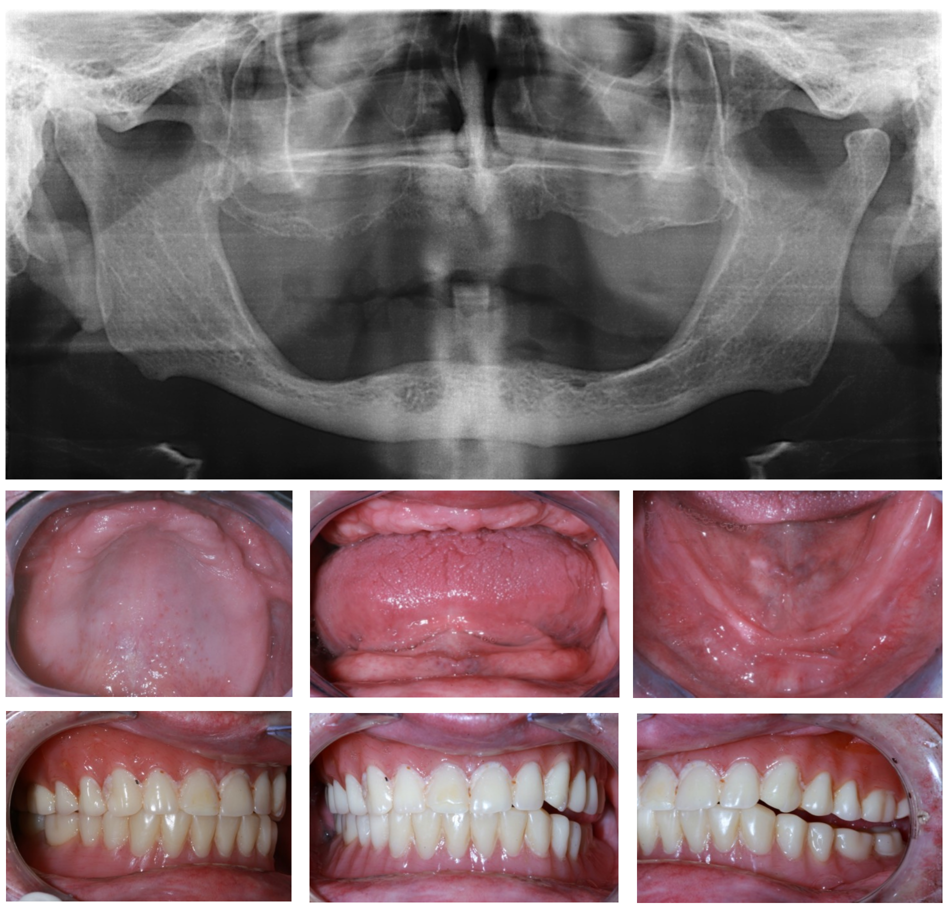

Fig 6: Pre-operative records.

available bone classification of Division C-h.[21] (Fig 7)

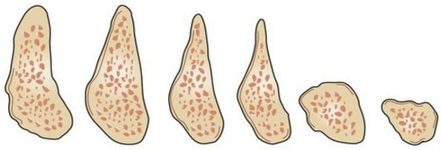

Fig 7: Misch Judy classification of available bone

Three options were presented to rehabilitate the masticatory system: conventional dentures, implant retained overdentures and full-arch fixed implant supported prostheses. After consideration, a conventional denture was selected for the maxilla and an implant supported, full-arch CAD/CAM Zirconia Prosthesis was selected for the lower.

TREATMENT

Following a prosthetically driven protocol, impressions were taken and models were fabricated. Record bases with wax rims, a facebow, and bite records were obtained to articulate the models on an articulator (Artex). A facial analysis and craniometric measurements[22] were performed to determine the vertical dimension of occlusion, lower face height, as well as the number and positioning of the implants on this mesio-cephalic human head. Neuromuscular analysis of the strong bite force and hypertonic muscles of mastication were also considered. All analyses were integral for a successful outcome. (Fig 8) A diagnostic wax-up was then fabricated.

The diagnostic wax-up was placed in the patients mouth and analyzed. Time was spent to modify the diagnostic wax-up, as this would be scanned and used as our prototype for the final prosthesis. Concepts taught at Christian Coachman's Digital Smile Design[23] were modified and applied (Fig 9) enabling us to design a prosthesis that would be a bit more human, more emotional, more artistic, more natural and more confident. As dentists, we are trained to focus on technical precision measured in millimeters. There may be a tendency to overlook the emotional side of treatment as seen by the patient. Instead of using still images as diagnostic tools, clips were taken from a short video of the patient grinning, smiling, laughing and just speaking….and then these images were shared with the patient in order to incorporate his opinions.

Once the wax-up met all of our criteria, scan prostheses were printed using additive manufacturing (AM). CBCT scans (iCat) were taken of the maxilla and mandible with the scan prostheses in place. Please note that the final prostheses were near completion before obtaining the CBCT scans and placing the implants. Truly a prosthetic driven treatment.

All too often, I see clinicians ordering scans before the diagnostic wax-up merely to view the available bone and visualize the anatomical landmarks. At Chairside Implant Services we believe that is backwards thinking, and with that approach, the digital CBCT scans are not being used to their full potential. The only way to plan the position of the implants is to see the desired position of the prosthetic teeth on

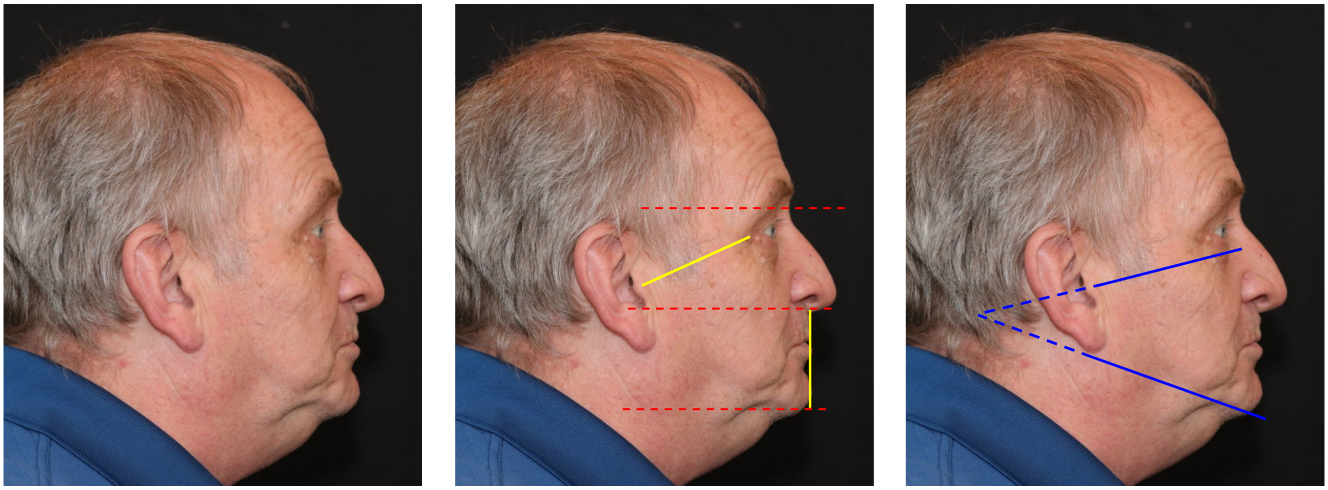

Fig 8: Applying craniometric measurements and facial analysis to determine the vertical dimension of occlusion, lower face height, as well as the number and positioning of the implants on the mesio-cephalic human head...along with neuromuscular analysis of the strong bite force, hypertonic muscles of mastication was crucial for a successful outcome.

Fig 9: Applying concepts taught by Christian Coachman's Digital Smile Design, we are able to design a prosthesis that is more human, more emotional, more artistic, more natural and more confident.

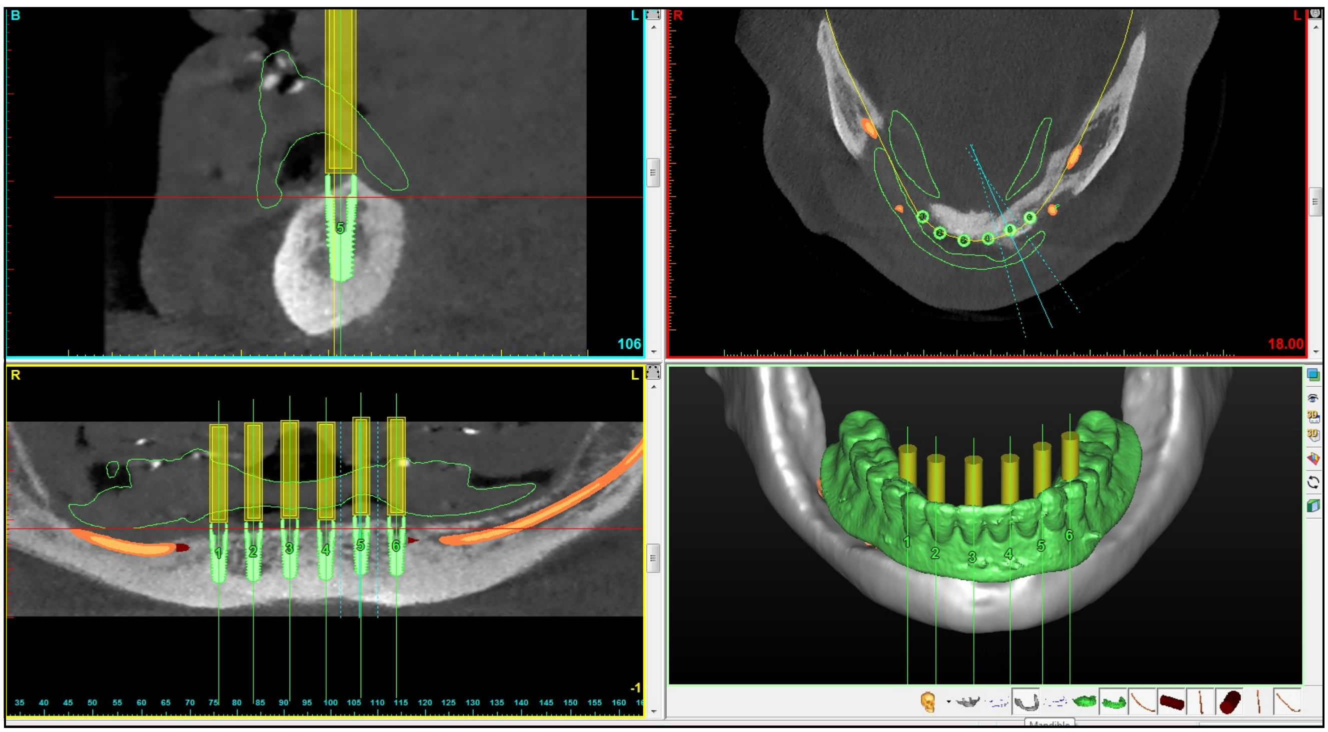

Fig 10a: Six dental implants planned in the mandible using Simplant software. All of the implant fixtures were planned somewhat parallel instead of tilting the distal most fixtures, a modification to Tischler's technique.

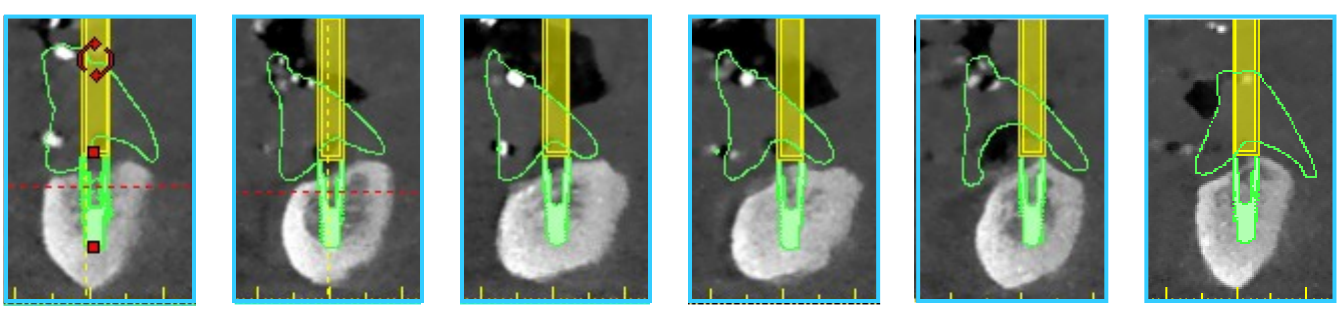

Fig 10b: Classic Division C-h available bone between the mental foramina.

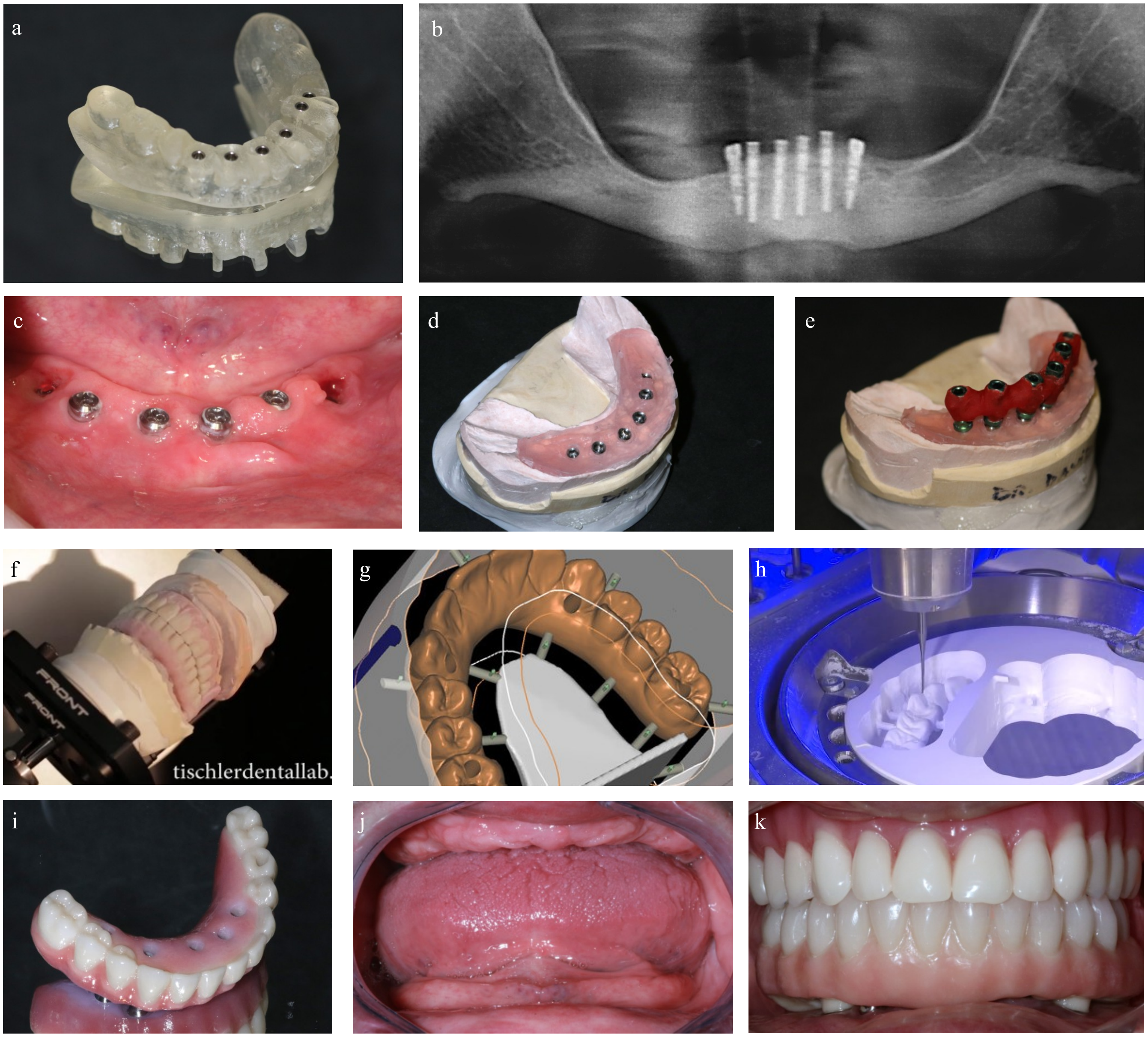

Fig 11a: CAD/CAM surgical guide printed from the Simplant plan. **b:** Surgical guide carried to the mouth for flapless placement of the fixtures. **c:** One week post-op. **d:** Master model. **e:** Verification jig. **f:** A wax-up being scanned at Tischler Dental Laboratory. **g:** Zirkonzahn's nesting software. **h:** Milling a zirconia prosthesis **i:** CAD/CAM PMMA temporary prosthesis. **j:** A look back at the pre-op condition. **k:** Final upper prosthesis and CAD/CAM PMMA temporary prosthesis delivered in the mouth.

the scan. A proven way to do this is to bring the desired prosthesis to the wax stage, duplicate it into a radiopaque material, scan the patient with that appliance, and then plan the implant positions.

Ultimately, one can transfer that plan and the virtual placement of the implants to the mouth with accuracy and precision, utilizing the scan to its full potential.

Once our scans were obtained with the scan prostheses, we were now able to place the implants, not only according to the available bone, but according to the prosthesis. Modifying Tischler's technique to accommodate this patient's anatomy, six implants (ScrewPlus, Implant Direct) instead of five, without angling the distal most fixtures, were designed between the mental foramina using digital software (Simplant, Dentsply). (Fig 10)

A CAD/CAM surgical guide was digitally printed from the Simplant plan and carried to the mouth for

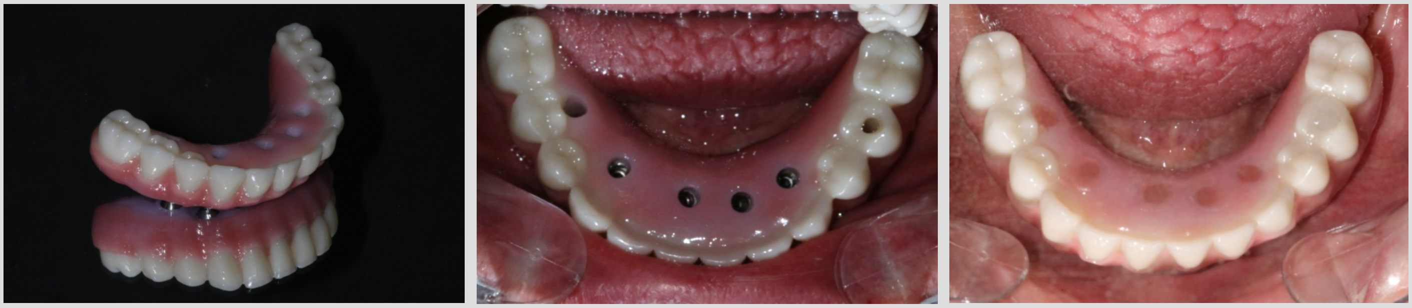

Fig 12: The final Prettau prosthesis.

flapless and non-invasive placement of the fixtures. (Fig 11) Transmucosal healing collars (Implant Direct) were placed the same day as implant placement. The diagnostic wax-up was processed in denture material, and the patient was transitioned into the temporary prostheses lined with soft material. (Kerr)

After a three month period of osseointegration, impressions and records were taken and a mandibular PMMA fixed prosthesis was delivered.

After a one month test drive of the PMMA prosthesis (Fig 11i), the patient reported comfort. The only deficiency was a space between the underside of the prosthesis and the soft tissue (Fig 11k). To correct this problem, the verification jig was broadened with acrylic and used as an impression tray to capture the soft tissue. This was poured, scanned and married to the existing digital file. This was the only necessary modification. The adjustment was made digitally and the zirconia Prettau prosthesis was milled, stained, sintered, fired, and delivered. (Fig 12)

DISCUSSION

Presented here is full mouth rehabilitation incorporating several digital modalities. From patient registration to manufacturing the mandibular prosthesis, a digital workflow was followed.

The only missing link in the digital workflow is that conventional fixture level implant impressions are still required. The laboratories are not yet accepting fixture level scans for full-arch prosthesis. Confidently, the lab managers assure me, “That is next”. I am hopeful that we will soon be able to acquire digital images of the implants to replace fixture level impressions for the master models.

It is an exciting time to practice dentistry as technology continues to advance. Incorporating technology into practice provides greater efficiency in delivering services as well as improved patient comfort.[25] I don’t know who coined the phrase but the future truly is now. Waiting another 1, 2 or 3 years to adopt or

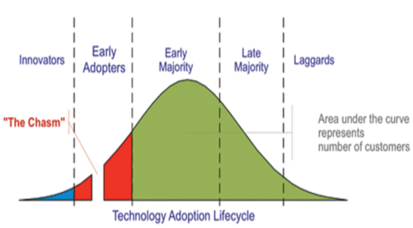

Fig 13: Technology Adoption Lifecycle and “Crossing the Chasm.”[24]

integrate these new areas of dentistry will leave you decades behind.

In the past, deciding to integrate technology was easy for me. On the Technology Adaptation Curve (Fig 13), I would lie between the Early Adopters and Early Majority. More recently, however, more thought goes into the integration of technology for me and in some instances I am in the Late Majority, not only because I am getting older but more so because the choices of technology are vast and almost too many to choose from. I certainly try to stay out of the Laggards category.

One has to make informed decisions regarding the choice of new technology, and that takes time. Also, along with the excitement of digital dentistry comes some fear and frustration with the cost, keeping up with the ongoing improvements and upgrades, and intimidation with the complexity of the new technology.[26]

Scanning and milling crowns is a practical step for many general practitioners. Some are hesitant because their team has the traditional process of making a crown mastered perfectly, efficient and profitable: *prep, impress and temp*...15minutes of doctor time, 15 minutes of assistant time and off to the lab it goes. This

Fig 14: Summary

is routine, efficient, and bread and butter for most.

At first, incorporating digital technology for the single tooth crown may be disruptive and upset your mastered routine and efficient workflow, but with adaptation you will find it better. The accuracy of the digital impression is superior to the PVS or polyether impression [27] and the milled restorations literally drop right in with none of the tedious occlusal or interproximal adjustments.

I have found that incorporating technology for the full-arch implant prosthesis has not been disruptive, but actually aids in the efficiency of the process. Acquiring the digital full-arch fixture level file via a digital scan is the next step.

Digital dentistry is more than just hype. When properly implemented and adequately educated, increased pleasure in practicing dentistry can be experienced and better care for your patients can be delivered.

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