Simon Benjamin Belissa

Maxillary bone regeneration with personalized titanium mesh trays

Universidade Fernando Pessoa

Faculdade de Ciências da Saúde

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Assinatura : _____

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RESUMO

O meu trabalho pretende comparar a efficacia das barreiras personalizadas em titanio com as barreiras convencionais e perceber as melhorias deste metodo. O objetivo é de perceber as vantagens das barreiras convencionais e suas limitações para as comparar com as novas barreiras produzidas com tecnologia CAD/CAM.

Este tema é muito importante porque a regeneração ossea nos maxilares é um tema complexo e que précisa ser ainda mais desenvolvido para ganhar em eficácia. Falta de osso pode trazer complicações não apenas esteticas, mas também na função mandibular, a qual precisa um equilibro perfeito.

A tecnologia CAD/CAM tem sofrido uma expansão grande e é importante tentar utilizar suas vantagens na confeção de dispositivos para auxiliar a regeneração ossea.

Palavras-chave: “Titanium” ; “mesh” ; “CAD” ; “CAM”; “bone” ; “regeneration” ; “personalized” ; “maxilar” ; “mandibular”

ABSTRACT

My essay intends to compare the efficiency between personalized titanium mesh trays and conventional ones and to understand the improvements between both. The main goal is to understand the perks of conventional membranes and how they should keep that way while trying to reduce the flaws.

This subject is really important because guided bone regeneration in maxillary bones is a complicated theme that requires enhancements to gain in efficiency. Lack of bone is those regions can lead to complications in esthetics but also in functionality of the mandibula because it requires a perfect equilibrium.

CAD/CAM technology is experiencing a big expansion and it was interesting to use its benefits towards producing pieces for guided bone regeneration.

Key-words: “Titanium” ; “Mesh” ; “CAD” ; “CAM” ; “Bone” ; “Regeneration” ; “Maxillary” ; “Mandibular” ; “Personalized”

DEDICATION

A mes parents, vous m'avez prouvé tout au long de ma vie qu'avec vous j'arriverais à suivre mes rêves aussi périlleux le chemin fût-il. Vous êtes des modèles de sagesse, courage et cœur pour moi. Je suis fier de vous et de votre force. Je vous aime.

A mon frère, pour son soutien quotidien sans lequel je ne serais pas qui je suis aujourd'hui. Tu auras forgé ma patience et mon caractère au fil des années.

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A mes oncles, tantes, cousins et cousines, pour votre gentillesse et bienveillance.

A mes amis, vous êtes comme ma famille. Les années qu'on aura vécu ici ensemble resteront dans mon cœur à vie et je suis chanceux de vous avoir à mes côtés.

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Thanks to all the teachers who surrounded me during this course and from whom I learned a lot.

SUMMARY

INDEX TABLE

CAD	Computer-Aided-Design
CAM	Computer-Aided-Manufacturing
CMF	Complex comminuted mandibular fractures
CT	Computed tomography
DICOM	Digital imaging and communications in medicine
GBR	Guided bone regeneration
PRF	Platelet-rich fibrin
PRP	Platelet-rich plasma
PTMT	Personalized titanium mesh tray
RP	Rapid prototyping
Ti-mesh	Titanium mesh
TMJ	Temporo-mandibular joint
TMT	Titanium mesh tray
VS	Virtual surgery

I. INTRODUCTION

Titanium meshes have been used for the past decades in many ways to restore lack of bones in different parts of the jaw. Being a biocompatible, biosafe and biostable element, it has been a major help in guided bone regeneration (GBR) especially for neck and head restorations. (J. Woo, et al., 2018) Nevertheless, this technique requires a huge amount of practice, time and luck to be successful as it was difficult to adapt conventional plates to cases as unique one from another. (J. Liu, Kerms D., 2014)

Due to the new breakthroughs in Computer-Aided-Design (CAD) and Computer-Aided-Manufacturing (CAM), scientists decided to apply it in reconstructive surgeries of the maxillary bones. (T. Sumida, et al., 2015) Personalized titanium mesh can be used for different types of interventions that we will develop throughout this paper such as alveolar bone regeneration previous to implants or balance facial symmetry in patients suffering from trauma or huge surgeries that have dealt important damage to their jaw. (J. Ma, et al., 2017) It can also fulfill a replacing roll in areas where bone was lost in various ways. It is not only a matter of appearance but also can improve balance and power to the temporo-mandibular joint (TMJ) to regain his purpose and capability. (T. Numajiri, et al., 2017)

In this paper, I would like to discover with details a new tendency in orthognathic and esthetic surgery and try to determine the best use and limits it has. In order so, I will firstly go through the basics of conventional titanium meshes; perks and flaws and then compare it with the personalized ones. As for everything, it is important to understand quickly the limits and boundaries of this new technic and discuss on what could be done in the future to improve, even more, bone regeneration in maxillary bones surgeries.

1. Methodology

This technique being relatively new, I decided to search for information on different online platforms such as B-ON, PUBMED, Google Scholar, Sci-Hub and Research Gate. I used the following key-words and narrowed my research to 2012-2018. I received 135 different articles in English and selected 25 of them that fitted the most my topic by selecting articles talking about CAD CAM technology applied on titanium meshes and selected only few articles talking about conventional ones to comprehend the subject in its whole.

II. DEVELOPMENT

1. Conventional titanium mesh trays

a. Indications

Titanium is a good match for bone regeneration and it has been known for many years. It is used in multiple surgeries but needed some improvement to become the gold standard barrier for guided bone regeneration. Thanks to its biocompatible, biosafe and biostable characteristics, the body can accept the mesh tray easily and avoid complications in tissues. (J. Liu, Kerms D., 2014) (G. Wang, et al., 2012)

First of all, vertical bone regeneration is needed for GBR used in pre-implant site to regain bone height and therefore stability for the implant. (T. Sumida, et al., in 2015) They are also used in complex comminuted mandibular fractures (CMF) to bond and stabilize the jaw between fractured pieces. Lastly, titanium mesh helps restoring bone in missing areas such as the angle of the mandibula or in different parts of the cheek to restore function and esthetic/symmetry of the patient.

- ✓ Pre-implant guided bone regeneration: It is common to observe bone recession in both maxillary bones due to different factors such as periodontological diseases, absence of tooth or systemic diseases. In order to regain a good volume of bone but within our defined limits, we use titanium mesh trays to guide the bone regeneration according to the limits they define. But it also helps for esthetics and functionality of the implant. They need to be removed after bone regeneration so it common to see resorbable titanium membrane that will avoid second surgery. (A. Alagl, M. Madi, 2018)

- ✓ Complex comminuted mandibular fractures: When a bone is fractured in multiple sites, titanium mesh tray can afford a link and solidify the whole fractured place. It acts as a chain bonding the pieces between one and another and strengthen them during reformation. (J. Ma, et al., 2017)

- ✓ Bone lack and balance: After surgery like tumor ablation or a trauma, absence of bone can lead to different defects. First of all, in edging parts, it can unbalance the esthetic of the face. For example, in the angle of the mandibula, it is important to regain bone to optimize the facial symmetry. Same thing for infra-orbital bone loss of the maxilla. (B. Lethaus, et al., 2010)

Balance is important not only for esthetic but also for functionality as the tempo-mandibular joint is complex and needs equilibrium to fulfill its full role. Therefore, all bone absence is detrimental in different aspects and makes it mandatory to restore. (M. Shehab, et al., 2017)

b. Guided bone regeneration with titanium mesh tray

To regenerate bone, titanium mesh trays are used in concomitance with particular bone grafts or/and bone substitutes. It all relies on migration of osteoblasts in the affected area and inhibiting the cells limiting bone formation. Therefore, you have four principles that need to regroup. You must have exclusion of epithelium and connective tissue, space maintenance, stability of the fibrin clot and primary wound closure. (J. Liu, Kerms D., 2014)

In order to regenerate bone, the body uses three types of mechanisms depending on mesenchymal cells. Osteogenesis forms and develops the bone even without undifferenced mesenchymal cells. Osteoinduction differentiates stem cells into osteo/chondroblasts thanks to growth factors taken from living bone. Finally, osteoconduction is the help of nearby muscles to grow around it as it has a biocompatible, biosafe and biostable surface. (Y. Rakhmatia, et al., 2013).

To obtain bone through those mechanisms, we use autogenous bone (provides the three mechanisms), allografts from cadaver (use osteoconduction and possibly Osteoinduction) and finally xenografts and alloplasts (osteoconductive). Moreover, its pores avoid him from blocking the blood supply. (J. Liu, Kerms D., 2014) (G. Wang, et al., 2012)

c. Limits

When using a commercial Ti-mesh, it is common to bend it to make it adaptable to the unique situation you are facing. This will reduce mechanical strength of the mesh. Commercial mesh trays have to be cut and the edgy parts can provoke damages to the tissues and lead to mesh exposure. (K. Sagheb, et al., 2017) This last factor is to be taken in account also as it could lead to failure in bone regeneration. According to T. Sumida, et al., in 2015, conventional titanium mesh lead to 23.1% of infections and mesh exposure. All of those problems,

additionally to the difficulty of the process and the time spent, undermined the role that titanium mesh tray can have so it had to be improved with CAD/CAM technology.

2. CAD-CAM Technology application on TMT

a. Computer-Aided-Design – CAD

In the last decade, computering helped improved surgery and medicine in general thanks to his affordability and preciseness. When performing a complex surgery, especially for CMFs, the exact orientation equilibrium between the different pieces is mandatory if you want to restore the original esthetic and function. By transposing it into a software that you can adapt to your willing and manipulate the skull, you enhance the perception of the topology. Thereby, surgeons can analyze the damages and bone lack and the surroundings to maximize bone regeneration in the situation. (J. Ma, et al., 2017)

One particular aspect of internal surgery is that it requires extreme 3D vision for the surgeon to be able to understand its surrounding. Computer-Aided-Design is the application of computed topography into a software that will rebuild the 3D version of the skull. In order so, it has to transform the CT data into Digital Imaging and Communications in Medicine, also known as DICOM, format. (P. Mildenberger, et al., 2002)

Computed Tomography is a measurement of X-Rays absorption from the different tissues and transform it into a 2D or 3D anatomical structure. We submit the patient through an X-ray beam rotating around an axis that allows reconstruction of different slices and link them dimensionally one to another. It is a good way of seeing-through without cutting and is highly discriminatory as it can differentiate a physical density delta of less than 1%. (E. Venkatesh, SV. Elluru-, 2017)

Once the data is process under DICOM format, it can be incorporated into a computer software that will transform it into a field of pixels. It is then possible to navigate throughout the skull and its layers. As you often find artefacts due to previous dental treatments you can also improve the image with 3D Laser Surface Scanning to implement a precise dentition into the software. (T. Ikawa, et al., 2016)

When the replication of the skull is done, it is now possible to start designing the Titanium mesh tray following the contours and edges of the maxillary bones perfectly. You obviously gain stability and strength as it is easier to balance forces throughout the tray but also avoid movements and displacements that can cause mesh exposures, infections or lesions to the soft tissues. (B. Lethaus, et al., 2010) By designing it directly fitted to the bone, you avoid excessive bending of the mesh and therefore avoid weakening. It is common to thicken the outer surface of healthy bone to make it even more adaptable and CAD is helpful to avoid excessive preparation. (T. Ikawa, et al., 2016)

One particular aspect of oral and maxillofacial surgery is its difficulty to take every variable into account. Surgeons have to train a lot and it was one important limit of using titanium mesh as they needed experience and training to achieve perfectly the procedure. With Computer-Aided-Design, it is possible to fabricate a virtual/physical simulation model and train the surgeon and give him a haptic sensation. Moreover, it helps the patient understanding what will happen, how it is solved and how it also relies on them in post-operation. A mutual trust is mandatory in such difficult procedures and CAD is helping to build it. (B. Lethaus, et al., 2010)

In unilateral situations, CAD technology uses mirroring of the non-defect side and enhance symmetry restoration and obviously helps regaining function that the healthy side is supposed to provide. (T. Ikawa, et al., 2016, J-S. Hou, et al., 2012)

In general, CAD will enable the surgeon to apprehend the situation, and then go straight to how it can be solved. It is timesaver but also preserve bone and the surroundings. With CAD technology, you can determine what bone volume you require and avoid excessive osteotomy in other parts. Physical models can be made to sculpt the customized mesh tray around it and be able to manufacture something that fits perfectly the entire structure.

b. Computer-Aided-Manufacturing

Once the titanium mesh is designed, it has to be manufactured before surgery. The appearance of Rapid Prototyping (RP) combined to different laser application made the perfect match for the situation. Being a new option in oral surgery, personalized titanium mesh trays (PTMT) do not have a gold standard of manufacturing yet. Various techniques are used in our articles, with little information on their effectiveness.

For starters, J. Ma, et al., in 2017, use Selective Laser Melting (SLM) to manufacture their mesh trays as well as T. Sumida, et al., in 2015. This method consists in sculpting into titanium pieces by reduction to obtain a personalized mesh tray.

In other cases, direct metal laser sintering (DMLS) is used by the rapid-prototyping machine. This time, it is an additive manufacturing technology and therefore the components are built up in layers by addition. (A. Tarsitano, et al., 2016)

Just like conventional Ti-mesh, personalized ones need also some additional preparation after manufacturing to enhance it properties and make it more efficient in guiding bone regeneration. T. Ikawa, et al., in 2016, faced an issue of hardness and had to soak it in acetone to strengthen the mesh. Additional polishing is often used on titanium mesh trays. Making them with CAD CAM technology increases the preciseness of the surface treatment and improve even more its characteristics.

3. Bone regeneration with CAD/CAM mesh trays

a. Prosthetically guided bone augmentation prior to implants

The principal limitation of implants is the alveolar bone necessity for a viable procedure. In a lot of cases requiring implant, the tooth has been missing for a long time and therefore leads to bone recession quickly. To expand the application of implant procedures, scientists have been working on various bone guided regeneration especially with conventional titanium mesh trays with the limits explored before. (A. Scarano, et al., 2017)

An important outcome is the viability of the implant and T. Sumida, et al., in 2015, compared both conventional and custom-made titanium mesh tray. The first comparation he makes is between simultaneous or not implantation case. Every cases in custom-made devices made that possible (13/13) but only 11/13 for the conventional ones. This is a gain of time and productivity as he shows also 3 more implants placed for personalized meshes.

To understand the final results, we must study how GBR worked for both. He then continues comparing them in term of mesh exposure and infection that happened in both situations. For both the difference is significant. Indeed only 7.7% of patients suffered from mucosal rupture and infection for the custom-made devices compared to the 23.1% of the

conventional ones. In their study, A. Scarano, et al., in 2017, observed mesh exposure during healing on even more cases (33%). In K. Sagheb's, et al., in 2017, study, he faced the same 33% of mesh exposure for his personalized trays but in all of the cases, he has been abled to regenerate enough bone for implant insertion. The particularity of his operation is evaluating the addition of platelet-rich fibrin (PRF) and platelet-rich plasma (PRP) in terms of regeneration and success. He concluded that it helps reducing mesh exposure and getting better bone augmentation. L. Ciocca, et al., in 2018, did not find as good results as the others. He faced 66% of mesh exposures but all of the implants were still viable after 2 years.

In terms of technicity, T. Sumida, et al., in 2015, also compared the operation time and number of screws used for GBR. A conventional mesh required in average 111.9 min (+/- 11.6) whereas custom-made devices required 75.28 min (+/- 18,5) and 1,31 screws (+/- 0,48) compared to 3.23 (+/- 0,73) in the same order.

To be safe, each implant and bone augmentation require specific conditions. For example, T. Sumida, et al., in 2015, explain that the mesiodistal end of the device should at least be 1mm away from the adjacent teeth to avoid infection. L. Coccio, et al., in 2018, mention the 1,5 mm safety-zone around each implant. They both mention the important part of CAM in perfect adaptation and stability of the titanium mesh in this procedure.

b. Restoring fractured bones

Titanium meshes are not only used for regeneration. They are also a support in bone fractures as they can help joining the fractured pieces to regain continuity and guide regeneration in a viable way. When a comminuted mandibular fracture happens, the patient is facing a situation with dozens of bone pieces scattered and fractured. The surgeon's role is not only to regain bone volume but also link every part to minimize the damage and maintain not only function but also reestablishing esthetic and symmetry.

In their study, P. Li, et al., in 2014, compared use of conventional and CAD/CAM ti-mesh in CMF. In this case we also observe a reduced operation time (54 min +/- 3.5 vs 78 min +/- 4) but additionally a reduced amount of bleeding (89.5 mL (+/- 5,4) vs 122.3 mL (+/- 7.6)).

Additionally, to the technical part, they compared the esthetic of both procedures. Firstly, they compared the level of mandibular symmetry (LMS). The CAD/CAM group shows

92% (+/- 4.2) of LMS compared to 83% (+/- 5.8) for the control group. This leads to a rise in satisfaction of the patient. There are no dissatisfied patients for personalized ti-mesh and 17% for the conventional plates.

Most of the articles mention the difficulty of adapting the titanium mesh trays to the contours of fractured sites in this type of procedures. Designing the plate especially for the particular situation helps adaptation and stability around the bone. Moreover, by making it already bended and adapted to the corners and edges, surgeons avoid tissue damage and perdition of the titanium mesh's strength by bending it excessively to make it adaptable when using commercial ones. (J. Ma, et al., 2017)

c. *Restoration of bone defect*

Bone regeneration can also be needed in cases of trauma without having to link the fractured pieces. Indeed, in different tumor excision or trauma, titanium mesh trays can guide in different part of the jaw the regeneration of bone to restore functionality and esthetics. In cases of mandibular or maxilla discontinuity, we also require a good adaptation of the device to the adjacent bone to maintain stability and avoid further damage to the tissues. Designing it for the special situation thanks to the CAD/CAM technology was made possible recently and in complex cases barely the unique solution.

A. Tarsitano, et al., in 2016, explain that a reconstruction should provide four things. Firstly, it should achieve facial symmetry and esthetic. It is one of the main reason a patient would do such a complex procedure. In the maxilla reconstruction, it should also provide support to the orbital content, reconstruct palatal surface and avoid communication between nasopharynx and the orbit. B. Lethaus, et al., in 2010, tell us that maxilla restoration is more difficult to achieve than the mandibular.

It is not only a problem of esthetics as A. Tarsitano, et al., in 2016, show us that it also helps regaining the power to swallow or to speak for the patient. The CMJ being a complex ensemble, a reconstruction need to be adapted perfectly and take everything into account. T. Ikawa, et al., in 2016, make the same point by describing the fact that the mesh needs to sustain the stress and forces during jaw function. They managed to restore the possibility to eat for the patient in 10 days and normal diet after 3 months. J-S. Hou, et al., in 2012, found out that this

technique was working also in his 15 cases of ameloblastoma patients that needed mandible reconstruction.

Titanium mesh trays can be used with different types of graft. In those situations, most of the authors used fibula graft. J-S. Hou, et al., in 2012, use it but explain that they are efficient in restoring the continuity of the maxillary bones but not for functional dental restoration. M. Shehab, et al., in 2017, in their study also use PRF in this situation and showed positive results to avoid wound dehiscence in post-op. In this particular type of intervention, the authors mentioned the important part of the computer-aided-design either for planning the operation for the surgeon but also for presenting the case to the patient with a mock-up and get a better perception. B. Lethaus, et al., in 2010, mention it by saying that it provides a better understanding of the process and outcomes for the patient and also the surgeon to get a better 3D interpretation of the operative site. J-S. Hou's, et al., in 2012, study gives us the same conclusion by talking of education of the patient but also reduction of the operation time and blood loss as seen in the other parts. Finally, G. Wang, et al., get to the conclusion in their 2012 study that using CAD CAM technology reduces operation time and errors, enhance stability and ensure a more precise fit.

In their study, J. Woo, et al., in 2018, use this technology and get to the conclusion that it could be used for large defects and big reconstructions. We have seen earlier that it was also efficient in large alveolar bone defect.

4. Limitations of personalized titanium mesh trays

a. Availability

Just as every innovations, personalized titanium mesh trays are bound to have lacks and limits. CAD/CAM technology requires certain knowledge and funds to be mastered. In B. Lethaus's, et al., in 2010, study, they get to the conclusion that due to the technicity of the software systems, this technique was limited to larger medical centers. T. Numajiri, et al., in 2017, getting to the same conclusion decided to guide professionals into building their own in-house PTMT.

A. Tarsitano, et al., in 2016, mention that one of the limitation is the knowledge of the software as it can take a long time to understand the software (Rhino in this situation) completely.

b. Time

It is a long process to design and manufacture custom-made ti-mesh trays. T. Numajiri, et al., in 2017, explain it was part of the objective of their study as they compared every length of the different parts of the procedure. They found an average of 4.1 hours of Virtual simulation, 12H of 3D printing time, 4 hours of pre-bending time and a 3 days total preparation time.

This lead us to a more recent study conducted by G. Orabona, et al., in 2018, in which the main objective was to reduce time and could potentially be reduced by 24H with their procedure. As seen before, some extra time is gained in operation time as surgeons have been training with virtual surgery. However, A. Tarsitano, et al., in 2016, mention the fact that, even with VS, a potential disadvantage could be the difficulty to adapt to intraoperative changing situations.

Some of the authors do not take the duration into account. It is especially a problem if we are facing a malignant disease. (G. Orabona, et al., 2018)

c. Cost

Manufacturing personalized titanium mesh trays does not only rely on the technicity of using the software and hardware. It is an expensive technique as it requires a lot of material not available everywhere. (G. Orabona, et al., 2018)

The authors don’t all agree on the price difference between conventional and personalized titanium mesh trays. In J. Ma’s, et al., in 2017, study, they describe the higher cost of PTMTs as one of the limitations of the technique without giving further explanations. A. Tarsitano, et al., in 2016, get to the same conclusion about being limited by the price of the machines and manufacturing. R. Bosc et al., in 2017, reported that it costs between 3000€ and 5000€ per patient.

However, in another study from M. Shehab, et al., in 2017, the authors are stating that their personalized titanium mesh trays cost relatively as much as conventional ones.

III. DISCUSSION

The first difference between authors we can notice is the percentage of mesh exposure they had. T. Sumida, et al., in 2015, in his comparison only had 7.7% of mesh exposure instead of 33% in A. Scarano, et al., study done in 2017 and K. Sagheb's, et al., also in 2017. It is difficult to explain the difference between those studies as they concern only a few patients but they all managed to restore enough bones for the implant to be viable. It seems that using PRP and PRF helps the Ti-mesh during GBR. The suited design of the mesh is one of the main reason of the better success percentage in custom-made Ti-mesh.

A lot of authors agree on the fact that is helping reducing operation time. P. Li, et al., in 2014 and T. Sumida, et al., in 2015, observed a reduction of 30%. This is due to the training surgeons could get via Virtual Surgery but also linked to the fact that now the titanium mesh is fully adapted to the operation site and can be placed with great ease. When placing implants and trays, surgeons have to respect certain spaces and lengths between pieces. The preciseness of CAD/CAM technology enables a safe environment for bone regeneration following every knows rules for GBR. (L. Coccio, et al., 2018)

Not all authors agree on the main limits of PTMTs. First of all, for some, the technique can only be used in large medical centers providing the material and technology needed for it. That's why they are trying to build low cost self-made PTMTs. (T. Numajiri, et al., 2017) (G. Orabona, et al., 2018). They both empathize on the fact that surgeons need to be formed to master the software and guides are required to train everyone quickly. CAD/CAM technology has the ability to be relatively easy to understand and handle. I do believe that this will not be a problem for a long time as 3D printers are becoming more affordable and that it will become easier to use after software and hardware reworks.

For authors, Rapid Prototyping still take time manufacturing personalized mesh trays and technology will improve quickly to gain time in production. It is not a real problem unless the situation is critical according to A. Tarsitano, et al., in 2016. I do believe though that it requires to maintain the operation site in the exact same condition as when it was scanned. In situations

of strong trauma or unstable bone location, loosing time while manufacturing can become a problem as it could lead to a non-fitted custom-made piece. I do believe some work need to be done on 3D printers and SLM to be able to reduce it as much as possible.

Finally, the main limit is obviously the price. Even if M. Shehab, et al., in 2017, stated that the cost was nearly the same. The cost-effectiveness of buying a 3D printing machine, forming the surgeons in using CT, transposing data through DICOM, designing and manufacturing need to be studied furthermore to be determined. It seems though that it is costing more if the printer is not used enough but the advantages are overpassing this limit as it can nearly guarantee success in bone regeneration in small or large bone defects. (A. Tarsitano, et al., 2016)

After describing how GBR works with titanium meshes, it was interesting to compare the efficacity of bone gain between different types of membranes in order to understand if personalized Ti-mesh should be the gold standard membrane in GBR. There are different types of non-resorbable membranes available such as polytetrafluoroethylene (PTFE) (expended or high dense) or resorbable membranes such as collagen or synthetic ones.

The problem with resorbable membranes is that they have an unpredictable degree of resorption. This can lead to early exposure and inflammatory process and will provide less stability than titanium mesh. Because of its smooth surface, Ti-mesh seems to be less susceptible to bacterial infections compared to resorbable membranes. (Y. Rakhmatia, et al., 2013). The risk of infection being higher in resorbable membranes, it seems to be more interesting to use PTMT as they appear to be less risky for the patient.

Comparing to PTFE membranes, different studies demonstrate that Ti-mesh maintains space with better predictability. However, thanks to their small pore size and its high density, d-PTFE membranes are resistant to bacterial infiltration. (Y. Rakhmatia, et al., 2013). Before it could be personalized, the main limits of Ti-mesh were the stiffness and sharp edges of the plate. CAD/CAM technology reduced those disadvantages and kept the amazing properties of titanium in guiding bone regeneration. (Y. Rakhmatia, et al., 2013).

Unfortunately, there is no study yet comparing personalized ti-mesh with other membranes used for GBR. We can only guess that they will be even better than regular ones who were already seen as one of the best membranes available. In a study written by A. Cucchi, et al., in 2017, we can see that both PTFE membranes and Ti-mesh have excellent results in

guiding bone regeneration but there were more surgical complications in conventional titanium meshes than PTFE. They would likely be reduced using CAD/CAM technology as seen before.

IV. CONCLUSION

This bibliographic comparison helps us perceiving the benefits and limits of using CAD/CAM technology in producing personalized titanium mesh trays. Conventional plates were already widely used in GBR but they were submitted to flaws that would reduce their usage.

CAD technology helped the surgeon planning his surgery but also the patient to fully understand the procedure. Designing a stable and fitted plate was one of the main goal and can be manufactured thanks to CAM technology. We observed a reduction of infections, exposure, operation time, bleeding and screws used compared to conventional meshes.

It is a recent possibility in maxillary bones surgery so studies are too recent and not yet a 100% relevant. Clinical trials should be done in wider groups using different types of membranes to compare effectiveness on guiding bone regeneration.

Even if this technique is yet available only in specific health centers, it should be more available to surgeons soon with new guides coming than can be used on free software. They will also reduce the time spent designing and technology will eventually reduce manufacturing time also.

Using personalized titanium mesh trays seems to be the best option in many cases involving large defects or trauma and should be used in the future even more in small regenerations thanks to the perks of being custom-made.

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