Development of a new type of surgical guides for dental implants by 3D printing

Elaboración de un nuevo tipo de guías quirúrgicas para implantes dentales mediante impresión 3D

Jefferson Henao[1]
Jhoan Sebastián Ramos[2]
Carlos H. Valencia[3*]
Ivonne Adams[4]
Carlos Alberto Rico[5]
Juan Manuel Escandón[6]
Daniela Echeverri-Cárdenas[7]

[1] Colombian. Technologist in Dental Mechanics. Santiago de Cali University, Cali, Colombia. E-mail: jeffersonhenao0411@gmail.com

[2] Colombian. Technologist in Dental Mechanics. Santiago de Cali University, Cali, Colombia. E-mail: sebas.ramos_14@hotmail.com

[3] Colombian. PhD. in Biomedical Sciences. Santiago de Cali University, Cali, Colombia, BEO Research Group. Corresponding author: carlos.valencia12@usc.edu.co

[4] Colombian. MsC. in Medical Law. Santiago de Cali University, Cali, Colombia. E-mail: ivonneadams@usc.edu.co

[5] Colombian. Bachelor of Education, Specialist in Environmental Education. Santiago de Cali University, Cali, Colombia. E-mail: carlosalbertoricoc@yahoo.com

[6] Colombian. MsC. in Polymer Science and Technology. National Service of Learning SENA, Cali Colombia. E-mail: jmescandon@misena.edu.co

[7] Colombian. Product Design engineer. National Service of Learning SENA, Cali Colombia. E-mail: danaeca@gmail.com

Received: 25- 09 - 2017 Accepted: 10-05-2018

How to cite: Henao, J., Ramos, J. S., Valencia, C. H., Adams, I., Rico, C. A., Escandon, J. M. & Echeverri-Cárdenas, D. (2018). Development of a new type of surgical guides for dental implants by 3D printing. *Informador Técnico*, 82(1), 78-89. doi: http://doi.org/10.23850/22565035.1005

Abstract

Surgical guides are indispensable biomedical devices for the proper insertion of dental implants; Currently, there are 2 types of guides available: the "restrictive" and the "non-restrictive", the former offering a greater degree of stability and accuracy, but at a very high cost. In this work we propose the development of a new type of guide that combines a prosthetic determination and the incorporation of tomographic information with 3D printing techniques to obtain a device with good fit and adequate accuracy, but at a lower price. The product obtained was elaborated in polylactic acid and showed good adaptation, stiffness and stability properties which can guarantee a good clinical performance. Although conventional guides are very economical, they present stability problems that compromise the safety of the surgical procedure and therefore the patient's health; With the proposed technique, a precise and stable surgical guide can be obtained at a reasonable price while preserving the principles of prosthetic predetermination and ensuring that surgical procedures are adequate and safe. The elaboration of the device by 3D printing from a prosthetic predominance is technically feasible, without major technical complexities and could be a real alternative to the restrictive guides which are still too complex and expensive.

Keywords: prototyped; polylactic acid; biodevice odontology; implantology.

Resumen

Las guías quirúrgicas son dispositivos biomédicos indispensables para la inserción adecuada de los implantes dentales; actualmente se dispone de 2 tipos de guías: las "restrictivas" y las "no restrictivas", siendo las primeras las que brindan un mayor grado de estabilidad y exactitud, pero a un costo muy elevado. En este trabajo se propone la elaboración de un nuevo tipo de guía que combina una determinación protésica y la incorporación de información tomográfica con técnicas de impresión 3D para obtener un dispositivo con buen ajuste y adecuada exactitud, pero a un menor precio. El producto obtenido fue elaborado en ácido poliláctico y mostró unas buenas propiedades de adaptación, rigidez y estabilidad lo que puede garantizar un buen desempeño clínico. Si bien las guías convencionales son muy económicas presentan problemas de estabilidad que comprometen la seguridad del procedimiento quirúrgico y por lo tanto la salud del paciente; con la técnica propuesta se puede obtener una guía quirúrgica precisa, estable y a un precio razonable conservando los principios de la predeterminación protésica y asegurando que los procedimientos quirúrgicos sean adecuados y seguros. La elaboración del dispositivo mediante impresión 3D a partir de una predominación protésica es técnicamente viable, sin mayores complejidades técnicas y podría ser una alternativa real a las guías restrictivas las cuales aún son demasiado complejas y costosas.

Palabras clave: prototipeado; ácido poliláctico; biodispositivo; odontología; implantologí.

Introduction

Implant-supported dental prosthetic rehabilitation is a procedure increasingly requested by patients due to its high success rates (Gómez de la Mata Galiana, Lora-Vázquez, Gómez de la Mata Galiana and Gutiérrez-Pérez 2006), it is estimated that only Approximately 5 million implants are placed per year in the United States of America (Boyce and Klemons, 2015).

A diagnostic and/or surgical guide is a biomedical device that allows the preparation of the surgical alveoli and the controlled insertion of the dental implants respecting the anatomical structures and guaranteeing that the future rehabilitation is adequate.

The success of the insertion and the subsequent rehabilitation of the implants depends mainly on a correct planning, which is carried out from a predetermination (Argüelllo, 2013); in partially edentulous patients, the predetermination is based on a diagnostic wax-up and on fully edentulous patients in a line or a replica of the prosthesis they are using, if it meets functional and aesthetic criteria (Oh and Saglik, 2008).

Once the predetermination has been made, in the case of entanglement, some clinical tests are carried out to evaluate the smile line, the labial support, the facial expression, and the intermaxillary height; if it is determined clinically that the predetermination meets the expectations, we proceed to elaborate the diagnostic guide whose purpose will be to determine the relationship between the bone base and the soft and hard tissue profiles in relation to implants, later it will be adapted to serve as a surgical guide in the orientation and positioning of dental implants (Biotti and García, 2014).

The guide is essential to contrast the information obtained through a tomographic study with a prosthetic predetermination elaborated based on clinical findings and the projection of rehabilitation parameters, allowing both surgical and prosthetic planning (Matta, Bergauer, Adler, Wichmann , and Nickenig, 2017), in surgery the main function of the guide is to allow the correct three-dimensional positioning of the implant in the bone structure (Volpato, Vasconcellos, Garbelotto, Manfro, and Özcan, 2013).

In general, diagnostic and surgical guides must possess properties of rigidity, stability, and precision to ensure accuracy and safety during implant insertion procedures (De Kok, Thalji, Bryington, and Cooper, 2014); Ideally, they should have incorporated radiopaque markers, be retentive and stable intraorally, comfortable, sterilizable and compatible with the tomographic technique (De Kok, *et al*., 2014).

The stability of the guide in partially edentulous patients is achieved by incorporating the remaining remnant teeth, for example Shotwell, Billy, Wang, and Oh (2005), propose a simple guide made with polymerizable photo resin that uses as support the teeth neighboring the area edentulous but in totally edentulous patients, stability becomes critical due to mobility problems, to ensure correct positioning and stability during surgical procedures it is possible to use dental implants that have been previously placed (Zandinejad, Abdel-Azim, Lin, and Morton, 2013) or surgical mini-screws or osteosynthesis to laterally fix the device (Cassetta, Mambro, Giansanti, Stefanelli, and How, 2014).

Types of guide

Surgical guides can be classified according to the limitation or restriction they offer during the time of surgical preparation or according to the manufacturing technique.

According to the restriction they can be non-restrictive, semi-restrictive or restrictive. The non-restrictive tells the surgeon the position of the implants in relation to the prosthesis, prevents greater control over direction or depth of milling which can cause errors of angulation, lack of parallelism or compromise of anatomical structures. The semi restrictive type incorporates a guide tube that corresponds to the initial drill of the preparation but the surgeon must continue freehand with the surgical protocol which can also cause complications, while the restrictive limits the vestibular or lingual positions and has depth stops which leads to the preparations will be accurate and in accordance with the planning (Stumpel, 2008).

Restrictive and semi restrictive guidelines can be obtained from the duplication of waxes or diagnostic lines, but it is also possible to use pre-existing prostheses, if they show similarity with the proposed prosthetic projection, in any case, they should incorporate radiopaque markers (De Kok *et al.*, 2014).

Depending on the manufacturing technique, the guide can be of two types: Classic or laboratory guide and computer-designed guide or CAD-CAM.

Classical or laboratory guide

This is the most common type of guide, originally designed to establish the relationship between the predetermination and the bone ridge without being very precise, but has undergone multiple modifications such as the incorporation of guide tubes in the sites of the perforations in a diameter that corresponds to the first strawberry, being considered as a semi restrictive or semi-strict guide (Melej, Ibañez, and Ilic, 2011).

In the guides, some modifications can be made such as the removal of the vestibular or lingual/palatal portion of the preparation area (guide rails) to improve visibility, ensure parallelism and decrease the intraosseous temperature during preparation by reducing friction and improve irrigation (Akça, Iplikçio◎lu, and Çehreli, 2002); or the incorporation of parallelism pins to guide the positioning of the drill during the surgical procedure (Patras, Martin, and Sykaras, 2012).

These devices are usually made from a sheet of thermoplastic acetate applied to the vacuum on a gypsum duplicate of the prosthetic predetermination and reinforced with transparent polymethyl methacrylate (PMMA), but there are alternative materials such as the photopolymerizable resin type Triad ® (Shotwell *et al.*, 2005).

In order to visualize radiographically the projection of the teeth in relation to the bony ridge, to the guide, some radiopaque markers are incorporated in the places where the implants would go; the most frequently used are pellets and metal tubes, gutta-percha and barium sulfate (Scherer and Roh, 2015); additionally, Zahran and Fenton (2010) proposed using a radiopaque silicone (vinyl polysiloxane) as a marker in order to identify the contours of the rehabilitation and its relationship with the bone flange.

Of the radiopaque materials used, the metal pellets are the least recommended since they only act as a position marker making it difficult to determine the trajectory of the future implant, while the tubes and the gutta-percha fulfill their function of being a guide and allowing to determine trajectories (Almog, Torrado, Moss, Meitner, and LaMar, 2002).

The main advantages of this type of guide are its low cost and ease of processing but it has as a disadvantage the inability to guarantee good stability and precision (Madriz and Martín, 2009). Furthermore, the relationship between the anatomical structures and the guide itself is not very accurate (Orentlicher, Goldsmith, and Abboud, 2012).

Computer-designed guide (CAD-CAM)

The development of programs to manage tomographic information allowed the emergence of the concept "Computer-guided implant surgery", which consists of the precise realization of a treatment plan from a computerized axial tomography and a prosthetic predetermination, since it provides an Accurate knowledge of the anatomy of the area and the possibility of designing the position of the implants, in addition through the manufacture of personalized guidance devices, the transfer of this information to the patient allows minimally invasive protocols and precise rehabilitations (Carlevaris and Armijo, 2013) .

As in the other types of guides, we start with a prosthetic predetermination that is scanned and complemented with the tomographic information to elaborate a device that is anchored to the maxillary bone to allow the insertion of the implants and the installation of the rehabilitation, which It is developed by rapid prototyping techniques (Marchack, Charles, and Pettersson, 2011).

By using software the information captured by the scanner is processed to determine the positions and dimensions of the implant in relation to the bone levels of width and height, this will allow to develop a guide that will transfer to the patient in a very precise way the position of the implants (Turbush and Turkyilmaz, 2012) and to project at the same time the planned prosthetic rehabilitation, in this way the technique grants a visualization of the three structures that are relevant in the planning (the bone with the anatomical details, the projected implants and the proposed prosthesis), (Sanna, Molly, and van Steenberghe, 2007).

The combination of the volumetric images of the bone with the information obtained through the scanning of the prosthetic predetermination, allows to realize prototyped surgical guides by means of CNC machining or 3D printing that incorporate implant images positioned virtually in a very realistic way (Ganz, 2015), with the shapes and dimensions of numerous trademarks leading to very safe surgical and rehabilitative procedures, because there is a true integration between the tomographic information, the surgical plan and the prosthetic plan (Greenberg, 2015).

Despite its high cost and requires a detailed and accurate planning process, the CAD-CAM guides are considered the Gold standard because they are restrictive, that is, they only allow the passage of milling cutters with an exact diameter and length. which guarantees the safety of the procedure, they also facilitate surgical procedures, reduce intra-surgical time, are stable and allow less invasive procedures (Molina *et al*., 2013; Narayanan, Vernekar, Kuyinu, and Laurencin, 2016).

Techniques of rapid prototyping in biomedical

The techniques of rapid prototyping (PR) were a contribution of engineering to health sciences, biomedical prototyping emerged in the late 1980s, initially for educational purposes (Nogueira, Alencar, Roque-Torres, and Groppo, 2015) but it was soon used in planning and performing surgical procedures.

Rapid prototyping includes different techniques such as stereoscopic lithography (SLA), selective laser sintering (SLS), molten deposition modeling (FDM), laminated objects manufacturing (LOM) and systems based on inkjet and three-dimensional printing (3DP), among others, that can be classified as an additive, subtractive and additive/subtractive techniques (Banoriya, Purohit, and Dwivedi, 2015).

3D printing is an additive technique, was developed by Hideo Kodama of the Nagoya Municipal Industrial Research Institute in 1981, it has the advantage of allowing the construction of complex shapes, including hollow structures and currently allows the use of various metallic or polymeric materials (Kaye, Goldstein, Zeltsman, Grande, and Smith, 2016).

The printing technique is based on obtaining a virtual model by scanning an object or by 3D modeling, to subsequently materialize the object by adding a material layer by layer; In the biomedical area, 3 selective laser sintering systems (SLS), fusion-deposition modeling and ink-jet printing are used (Martelli *et al*., 2016).

The SLS uses a laser to selectively fuse the material particles during the construction of the object; molten deposition modeling is based on the same principle as classical two-dimensional printing and constructs the object by depositing layers of small pearls of material; while inkjet printing uses a printhead that deposits thermal ink or other material to form the object (Martelli *et al*., 2016).

The main materials currently used for 3D printing are thermoplastic polymers such as acrylonitrile butadiene styrene (ABS), polylactic acid (PLA), polyamide (PA), polycarbonate (PC), as well as thermosetting polymeric materials such as resins. epoxies (Wang, Jiang, Zhou, Gou, and Hui, 2017).

Technique proposed

This article presents a new method for developing low-cost surgical guides incorporating a prosthetic predetermination and 3D technology to convert the diagnostic guide into a rigid and precise surgical guide, using polylactic acid (PLA) as a thermoplastic material.

This work was carried out in two phases: design and prototyping.

The clinical description of the patient

It is a totally edentulous patient with a total prosthesis, to which the pre-prosthetic evaluation was made:

- Evaluation of lip support principles
- Analysis of the smile line
- Vertical dimension measurement
- Study of facial profiles and aesthetics

Once the examination was carried out, it was determined that it was feasible to use the prosthesis as a prosthetic predetermination, which is a usual procedure (De Kok *et al*., 2014).

Preparation of the diagnostic guide

The prosthetic predetermination was doubled (waxed or lined), in this case, the patient's prosthesis was given an alginate impression and a duplicate was prepared by casting in self-curing polymethylmethacrylate (PMMA), to obtain an acrylic model (Figure 1).

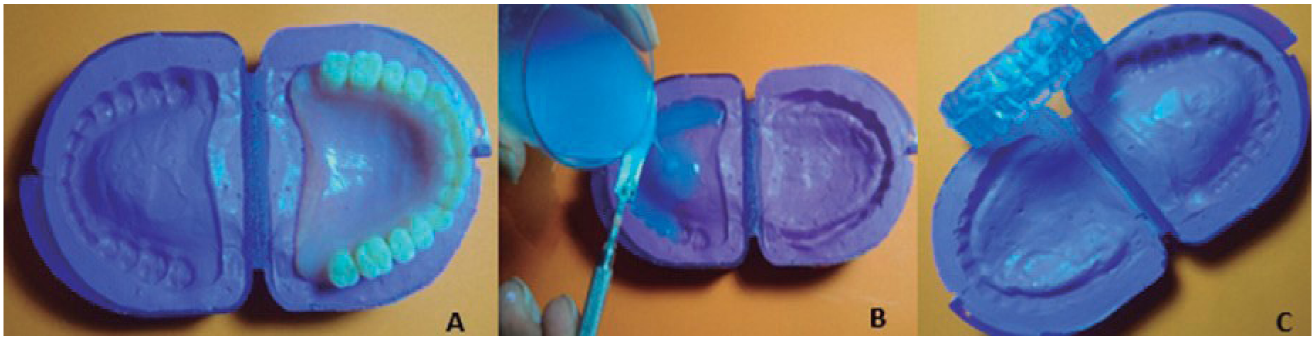

Figure 1. Duplication process of the prosthesis. A: Duplicate; B. Pouring with polymethyl methacrylate (PMMA); C: Obtaining the duplicate of the prosthesis
Source: the authors.

Perforations were made in the acrylic model, in the areas corresponding to the teeth where it was proposed to place the implants; at this point, it is necessary to take into account that normally the number of implants will depend on the type of rehabilitation planned, for a fixed rehabilitation 6 to 8 are recommended and for a removable one (on denture) 3 or 4 implants, preferably splinted, in this case, several sites were selected (Figure 2).

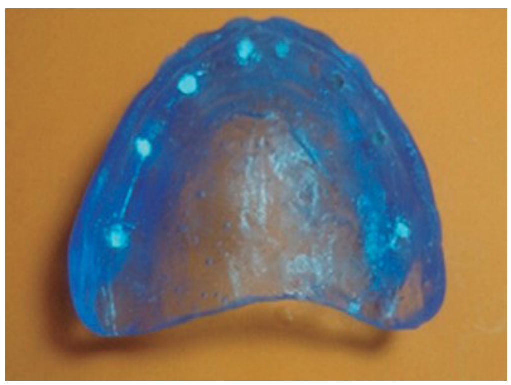

Figure 2. Diagnostic guide in PMMA with radiopaque markers in the proposed areas to place the implants
Source: the authors.

Clinical verification of the guide and request for tomographic examination

The relative stability of the device was verified in the patient; it was not necessary, but if it is relevant, a readaptation can be carried out in situ with PMMA or with silicone for relining, and the tomographic examination with the guidance in position is requested (Figure 3).

Figure 3. Tomographic examination. A: Guide in PMMA placed on the patient
Source: the authors.

Revo tomographic information and repositioning of the position of the implants

If the tomographic evidence indicates the repositioning of the areas where the implants are going to be, the new positions in the tomography are determined and they are transferred to the guide by making new perforations.

Development of the 3D surgical guide

Once the definitive positions of the implants are determined, the guide is scanned in PMMA to obtain a duplicate in polylactic acid (PLA) by 3D printing.

The guide was covered with white radiopaque paint, since it generates greater contrast with the base and highlights details of the piece, making the 3D scanner more accurately capture the shapes and textures of the product. Later it was placed on a black base with reflective points that function as position targets for the scan, which at the same time were located in the guide at strategic points (Figure 4).

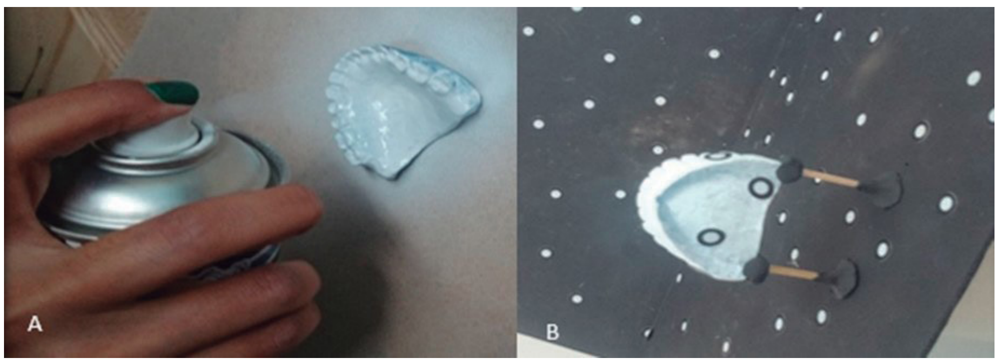

Figure 4. Determination of position targets
Source: the authors.

We proceeded to scan the device using a Handyscan 3D to obtain the digital representation of the guide at the highest resolution (0.2 mm) (Figure 5).

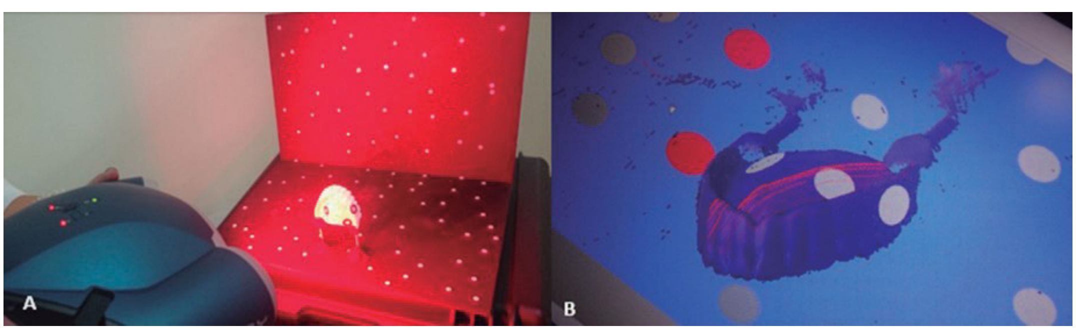

Figure 5. Scan process of the diagnostic guide
Source: the authors.

Once the digital representation in the form of a polygonal mesh was obtained, a mesh refinement was carried out using the Rapidform XOR3 software, reaching a generation of the preliminary surface, which was subsequently polished in the SolidWorks 2013 software, where the definitive solid was obtained. of the guide.

To finish the prototyping process, the 3D model of the guide was exported and finally, the G code was generated to print it in PLA with the Prusa Tairona 3D printer at a resolution of 0.1 mm, (Figure 6).

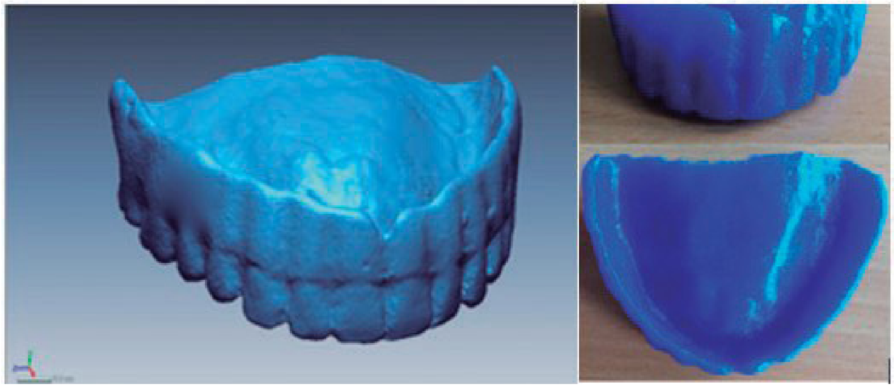

Figure 6. Refinement of surfaces and obtaining three-dimensional printing
Source: the authors.

Finally, the finished product was drilled in the areas where the implants would go, medical-grade steel guide tubes were adapted to turn it semi-restraint and the lateral guides were adapted to guarantee stability during the surgical procedures (Figure 7)

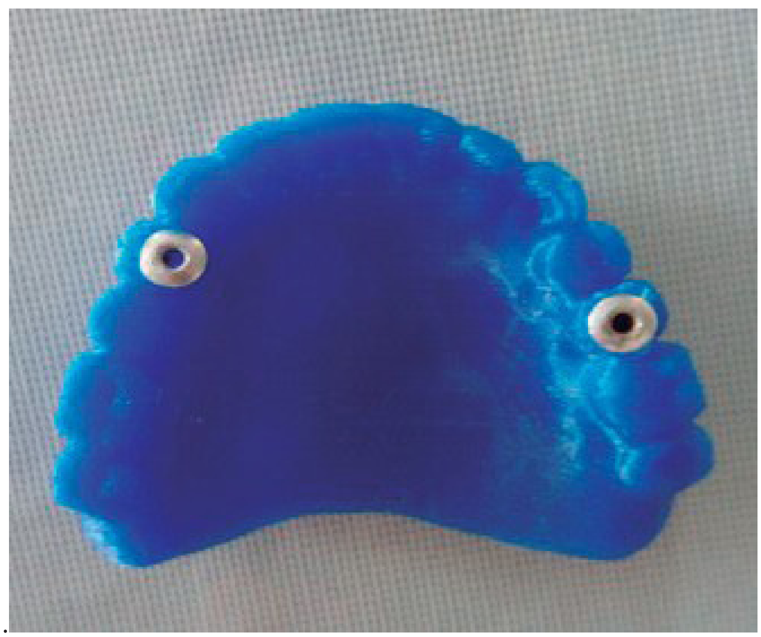

Figure 7. A printed guide with 2 guide tubes in position and 2 lateral markers for osteosynthesis screws
Source: the authors.

Discussion

The guide for thermoplastic splint type implants is the most used due to its low cost and ease of manufacture, however it has problems such as lack of rigidity which influences the adaptation and depending on the contrast medium used it can be difficult to establish a good relationship between the prosthetic predetermination and the bony ridge, some authors such as Zahran and Fenton (2010) have proposed to change the contrast medium for a radiopaque silicone, however in this work the use of gutta-percha in bars with good condensation allowed good vision of the insertion axis of the future implants as can be seen in figure 3 B.

In a review carried out by Boyce and Klemons (2015), among the main complications related to surgical guides are guide fracture, lack of stability, increase in temperature during intraosseous preparation and decrease invisibility.

Misir, Sumer, Yenisey, and Ergioglu (2009) compared the generation of heat during surgical preparations with and without surgical guidance finding significant differences, however it is accepted that the use of a guide will reduce the risks inherent in the procedure (Aljadi, Thompson, Izumi, and Ziebert, 2011) propose a semi restrictive guide design that combines the one of rail with the incorporation of guide tubes, which would allow the initial preparation in a precise way (using the tubes) and the reduction of heat by friction in the final stage of the preparation when using a tongue groove.

The lack of stability of the guide is considered one of the most important risk factors directly influencing the agreement or not between the position of the implants and rehabilitation, in an attempt to control this factor has come to propose the use of minimizers to support the guide in mucosal or unstable ridges (Simon, 2002), or occlusal stops to verify the correct position of the guide during the preparations (Briccoli, Barone, and Clauser, 2012).

If it is possible to guarantee the stability of the conventional guide, the procedure can be as safe as a computer-guided system (Barnea, Alt, Kolerman, and Nissan, 2010), but even these should be fixed to the bone ridge by means of osteosynthesis screws for guarantee its accuracy (Verhamme, Meijer, Bergé, and Maal, 2015).

In a study carried out by Matta *et al*., (2017) they find that both the thermoplastic guide (classic) and the CAD-CAM are suitable for transferring planning information to the clinical environment, however, it must be taken into account that this study It was performed in partially edentulous patients and therefore the guides were tooth-supported; As already mentioned in patients without teeth, the soft intraoral tissues, of a mobile nature, are not a guarantee of the stability of the prosthesis and this should be reinforced with some of the aforementioned methods.

In the type of device proposed in this work it was possible to guarantee the accuracy of the guide from a predetermination that was first adapted clinically and subsequently duplicated in a stable and resistant material, on the other hand, guide tubes were incorporated to improve the accuracy and they included lateral intraosseous anchors with osteosynthesis screws to guarantee a perfect fit between the guide and the bone flange.

Conclusions

Although conventional guides are very economical, they present stability problems that compromise the safety of the surgical procedure and therefore the patient's health; With the proposed technique, a precise and stable surgical guide can be obtained at a reasonable price while preserving the principles of prosthetic predetermination and ensuring that surgical procedures are adequate and safe.

The development of the device by 3D printing from a prosthetic predominance is technically feasible, without major technical complexities and could be a real alternative to restrictive guidelines that are still too complex and expensive.

References

Akça, K., Iplikçio◎lu, H., y Çehreli, M. C. (2002). A surgical guide for accurate mesiodistal paralleling of implants in the posterior edentulous mandible. *Journal of Prosthetic Dentistry, 87*(2), 233–235. doi: https://doi.org/10.1067/mpr.2002.120900

Aljadi, M., Thompson, G. A., Izumi, M., y Ziebert, G. J. (2011). A technique for fabricating a 2-part surgical template. *Journal of Prosthetic Dentistry, 106*(1), 57–60. doi: https://doi.org/10.1016/S0022-3913(11)60094-2

Almog, D. M., Torrado, E., Moss, M. E., Meitner, S. W., y LaMar, F. (2002). Use of imaging guides in preimplant tomography. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics, 93*(4), 483–487. doi: https://doi.org/10.1067/moe.2002.121389

Argüelllo González, J. E. (2013). Cirugía guiada protésico-quirúrgica: Aplicación de una nueva técnica. *Tecnica Dental, 80*(80), 28–32.

Banoriya, D., Purohit, R., y Dwivedi, R. K. (2015). Modern trends in rapid prototyping for biomedical applications. *Materials Today: Proceedings, 2*(4–5), 3409–3418. doi: https://doi.org/10.1016/j.matpr.2015.07.316

Barnea, E., Alt, I., Kolerman, R., y Nissan, J. (2010). Accuracy of a laboratory-based computer implant guiding system. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology, 109*(5), e6–e10. doi: https://doi.org/10.1016/j.tripleo.2010.01.001

Biotti Picand, J., y García Nieto, J. (2014). Técnica simplificada en la rehabilitación del desdentado. *Revista Clínica de Periodoncia, Implantología Y Rehabilitación Oral, 7*(1), 17–20. doi: https://doi.org/10.4067/S0719-01072014000100004

Boyce, R. A., y Klemons, G. (2015). Treatment planning for restorative implantology. *Dental Clinics of North America, 59*(2), 291–304. doi: https://doi.org/10.1016/j.cden.2014.10.009

Briccoli, L., Barone, R., y Clauser, C. (2012). A technique for fabricating a definitive immediate implant-supported prosthesis for the edentulous mandible. *Journal of Prosthetic Dentistry, 108*(3), 196–199. doi: https://doi.org/10.1016/S0022-3913(12)60148-6

Carlevaris, B., y Armijo, A. (2013). Precisión en cirugía guiada por ordenador. *Dental Tribune Hispanic & Latin America, 21*, 20–23.

Cassetta, M., Mambro, A. Di., Giansanti, M., Stefanelli, L. V, y How, E. B. (2014). How does an error in positioning the template affect the accuracy of implants inserted using a single fixed mucosa-supported stereolithographic surgical guide? *International Journal of Oral & Maxillofacial Surgery, 43*(1), 85–92. doi: https://doi.org/10.1016/j.ijom.2013.06.012

De Kok, I. J., Thalji, G., Bryington, M., y Cooper, L. F. (2014). Radiographic stents: Integrating treatment planning and implant placement. *Dental Clinics of North America, 58*(1), 181–192. doi: https://doi.org/10.1016/j.cden.2013.09.008

Ganz, S. D. (2015). Three-Dimensional Imaging and Guided Surgery for Dental Implants. Dental Clinics of North America, 59(2), 265–290. doi: https://doi.org/10.1016/j.cden.2014.11.001

Gómez de la Mata Galiana, J., Lora-Vázquez, M., Gómez de la Mata Galiana, G., y Gutiérrez-Pérez, J. L. (2006). Planificación y rehabilitación inmediata en la cirugía mínimamente invasiva. *Rcoe, 11*(2), 221–227. doi: https://doi.org/10.4321/S1138-123X2006000200006

Greenberg, A. M. (2015). Digital Technologies for Dental implant treatment planning and guided surgery. *Oral and Maxillofacial Surgery Clinics of North America, 27*(2), 319–340. doi: https://doi.org/10.1016/j.coms.2015.01.010

Kaye, R., Goldstein, T., Zeltsman, D., Grande, D. A., y Smith, L. P. (2016). Three dimensional printing: A review on the utility within medicine and otolaryngology. *International Journal of Pediatric Otorhinolaryngology, 89*, 145–148. doi: https://doi.org/10.1016/j.ijporl.2016.08.007

Madriz, G., y Martín, A. (2009). Férulas quirúrgicas en Implantología. *Cient. Dent, 6*, 165–175.

Marchack, C. B., Charles, A., y Pettersson, A. (2011). A single appointment protocol to create a partially edentulous CAD/CAM guided surgical template: A clinical report. *Journal of Prosthetic Dentistry, 106*(6), 346–349. doi: https://doi.org/10.1016/S0022-3913(11)00158-2

Martelli, N., Serrano, C., Van Den Brink, H., Pineau, J., Prognon, P., Borget, I., y El Batti, S. (2016). Advantages and disadvantages of 3-dimensional printing in surgery: A systematic review. *Surgery (United States), 159*(6), 1485–1500. doi: https://doi.org/10.1016/j.surg.2015.12.017

Matta, R. E., Bergauer, B., Adler, W., Wichmann, M., y Nickenig, H. J. (2017). The impact of the fabrication method on the three-dimensional accuracy of an implant surgery template. *Journal of Cranio-Maxillofacial Surgery, 45*(6), 804–808. doi: https://doi.org/10.1016/j.jcms.2017.02.015

Melej, C., Ibañez, C., y Ilic, D. (2011). Planificación quirúrgica digital guía quirúrgica semi estricta e implantes alternativos al sistema original ABSTRACT. F*undación Juan José Carraro, 34*, 1–13.

Misir, A. F., Sumer, M., Yenisey, M., y Ergioglu, E. (2009). Effect of surgical drill guide on heat generated from implant drilling. Journal of Oral and Maxillofacial *Surgery, 67*(12), 2663–2668. doi: https://doi.org/10.1016/j.joms.2009.07.056

Molina, I. C., Molina, G. C., Bez, L., Magini, R. D. S., Ángela, C., y Volpato, M. (2013). Guided surgery in implantology practice. *Revista Odo, 17*(2), 117–122.

Narayanan, G., Vernekar, V. N., Kuyinu, E. L., y Laurencin, C. T. (2016). Poly (lactic acid)-based biomaterials for orthopaedic regenerative engineering. *Advanced Drug Delivery Reviews, 107*, 247–276. doi: https://doi.org/10.1016/j.addr.2016.04.015

Nogueira, P., Alencar, B., Roque-torres, G. D., y Groppo, F. C. (2015). Utilización del prototipado rápido en la odontología. *Rev Estomatol Herediana, 25*(2), 167–174. doi: https://doi.org/10.20453/reh.v25i2.2463

Oh, W. suk, y Saglik, B. (2008). A simple method to duplicate a denture for an implant surgical guide. *Journal of Prosthetic Dentistry, 99*(4), 326–327. doi: https://doi.org/10.1016/S0022-3913(08)60072-4

Orentlicher, G., Goldsmith, D., y Abboud, M. (2012). Computer-guided planning and placement of dental implants. *Atlas of the Oral and Maxillofacial Surgery Clinics of North America, 20*(1), 53–79. doi: https://doi.org/10.1016/j.cxom.2011.12.004

Patras, M., Martin, W., y Sykaras, N. (2012). A novel surgical template design in staged dental implant rehabilitations. *J Oral Maxillofac Res, 3*(2), e5–e5. doi: https://doi.org/10.5037/jomr.2012.3205

Sanna, A. M., Molly, L., y van Steenberghe, D. (2007). Immediately loaded CAD-CAM manufactured fixed complete dentures using flapless implant placement procedures: A cohort study of consecutive patients. *Journal of Prosthetic Dentistry, 97*(6), 331–339. doi: https://doi.org/10.1016/S0022-3913(07)60021-3

Scherer, M. D., y Roh, H. K. (2015). Radiopaque dental impression method for radiographic interpretation, digital alignment , and surgical guide fabrication for dental implant placement. *The Journal of Prosthetic Dentistry, 113*(4), 343–346. doi: https://doi.org/10.1016/j.prosdent.2014.02.022

Shotwell, J. L., Billy, E. J., Wang, H. L., y Oh, T. J. (2005). Implant surgical guide fabrication for partially edentulous patients. *Journal of Prosthetic Dentistry, 93*(3), 294–297. doi: https://doi.org/10.1016/j.prosdent.2004.12.013

Simon, H. (2002). Enhancing the accuracy of implant placement. *Thre Journal of Prosthetic Dentistry, 17*(2), 229–232. doi: https://doi.org/10.1067/mpr.2002.121824

Stumpel, L. J. (2008). Cast-based guided implant placement: A novel technique. *Journal of Prosthetic Dentistry, 100*(1), 61–69. doi: https://doi.org/10.1016/S0022-3913(08)60140-7

Turbush, S. K., y Turkyilmaz, I. (2012). Accuracy of three different types of stereolithographic surgical guide in implant placement: An in vitro study. *Journal of Prosthetic Dentistry, 108*(3), 181–188. doi: https://doi.org/10.1016/S0022-3913(12)60145-0

Verhamme, L. M., Meijer, G. J., Bergé, S. J., y Maal, T. J. J. (2015). The use of first stage bone augmentation screws to stabilize the surgical template in the second stage. *International Journal of Oral and Maxillofacial Surgery, 44*(6), 781–784. doi: https://doi.org/10.1016/j.ijom.2015.01.010

Volpato, C. A. M., Vasconcellos, D. K., Garbelotto, L. G. D., Manfro, R., y Özcan, M. (2013). A modified surgical template with dual function. *Journal of Prosthetic Dentistry, 110*(3), 232–233. doi: https://doi.org/10.1016/S0022-3913(13)60364-9

Wang, X., Jiang, M., Zhou, Z., Gou, J., y Hui, D. (2017). 3D printing of polymer matrix composites: A review and prospective. *Composites Part B: Engineering, 110*, 442–458. doi: https://doi.org/10.1016/j.compositesb.2016.11.034

Zahran, M. H., y Fenton, A. (2010). A radiopaque implant template for partially edentulous patients. *The Journal of Prosthetic Dentistry, 103*(6), 390–392. doi: https://doi.org/10.1016/S0022-3913(10)60085-6

Zandinejad, A., Abdel-Azim, T., Lin, W. S., y Morton, D. (2013). Fabrication of a fixed multipurpose template retained by existing dental implants. *Journal of Prosthetic Dentistry, 110*(2), 144–146. doi: https://doi.org/10.1016/S0022-3913(13)60356-X