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A direct metal laser sintering (DMLS) root analogue implant placed in the anterior maxilla. Case report

BACKGROUND: *Modern cone beam computed tomography (CBCT) acquisition and three-dimensional (3D) image processing, combined with direct metal laser sintering (DMLS), allows custom-made, root-analogue implants (RAIs).*
PURPOSE: *To demonstrate how DMLS permits customized titanium RAI production, with immediate insertion and restoration in a fresh extraction socket of the anterior maxilla.*
MATERIALS AND METHODS: *A titanium RAI perfect copy of the radicular unit needed for replacement was created by customized DMLS, and inserted into a fresh extraction socket of the esthetic area of the anterior maxilla.*
RESULTS: *Follow-up after 1 year: the DMLS RAI implant showed a satisfactory functional and esthetic integration, with no bone resorption or soft tissue recessions.*
CONCLUSIONS: *The production of customized DMLS RAIs opens new interesting perspectives for immediate implantation.*

KEY WORDS: Direct metal laser sintering, Root analogue implant

Introduction

In 2012 we published, for the first time ever, an article focussing on the construction of custom-made roots. Our research has brought us to developing the same for the anterior maxilla.
Immediate implant placement is the insertion of an implant immediately after surgical extraction [1,2] which reduces treatment time and cost, with fewer surgical sessions and a positive impact on the patient [1,3]; furthermore, it may help to place the fixture in an ideal 3D position, enhancing tissue maintenance, helping counteract alveolar ridge contraction [4,5]. However, it can be difficult to obtain sufficient primary stability [6,7], due to a discrepancy between the fixture and the socket [2,3,6,7]. Primary stability is usually obtained by placing tapered or wide diameter implants [2,3,6,7]. One possible alternative is a custom-made, root-analogue implant (RAI) [8,9]. Several techniques have been noted in literature [8-14]. Recently modern additive manufacturing (AM) technologies have opened new interesting perspectives for custom-made RAIs [8,9,15]. With DMLS, a powerful laser beam is directed onto a bed of titanium micro-powders fusing them in accordance to a computer-assisted-design (CAD) file to generate thin metal layers [16,17] until the desired 3D object is created, without post-processing [16,17]. Several human histological/ histomorphometric studies have documented the bone response to DMLS titanium implants [18,19]; the clinical performance of DMLS titanium implants has been investigated, and satisfactory outcomes have been reported [20-23]. DMLS can be used to create custom-made RAIs together with cone beam computed tomography (CBCT) acquisition and 3D image conversion creating perfect copies of the radicular units to be replaced as custom-made RAIs, [8,9,15]. Although DMLS has proven to be an effective technique for manufacturing custom-made RAIs [15], there is still limited clinical data in literature [9,24,25]; to date, there are no studies reporting on these implants in the esthetic area.
This report demonstrates how DMLS technology permits customized titanium RAI, with immediate insertion in a fresh extraction socket of the anterior maxilla.

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Materials and Methods

A 45-year-old male with a fractured non-restorable lateral right maxillary incisor was selected for the present study. The procedure for the production of the RAI was as previously described [9,24,25]. After a CBCT scan (CS9300®, Carestream Health, Rochester, NY, USA), DICOM datasets were analyzed with 3D reconstruction software (Mimics®, Materialise, Leuven, Belgium), segmentation was performed and a 3D reconstruction of the maxilla and the residual, non-restorable root were obtained (Fig. 1). A "virtual extraction" was performed, isolating the root as a stereolithographic (STL) file that was elaborated using reverse-engineering software (ProEngineering CAD 3D®, PTC Group, Needham, MA, USA); the root was processed and the prosthetic abutment was added. The diameter of the implant neck was then reduced in the area in contact with the thin buccal bone: this vestibular slice was obtained using software by Magics®, Materialise (Leuven, Belgium) (Fig. 2). The RAI was produced via DMLS, using Ti–6Al– 4V alloy powder, with a particle size of 25-45 micro-meters as the basic material [9]. The study complied with the principles outlined in the Declaration of Helsinki on experimentation involving human subjects (2008).
Surgical and prosthetic procedure were as previously described [9]. After local anaesthesia with articaine 4% (containing 1:100,000 adrenaline) an intrasulcular inci-

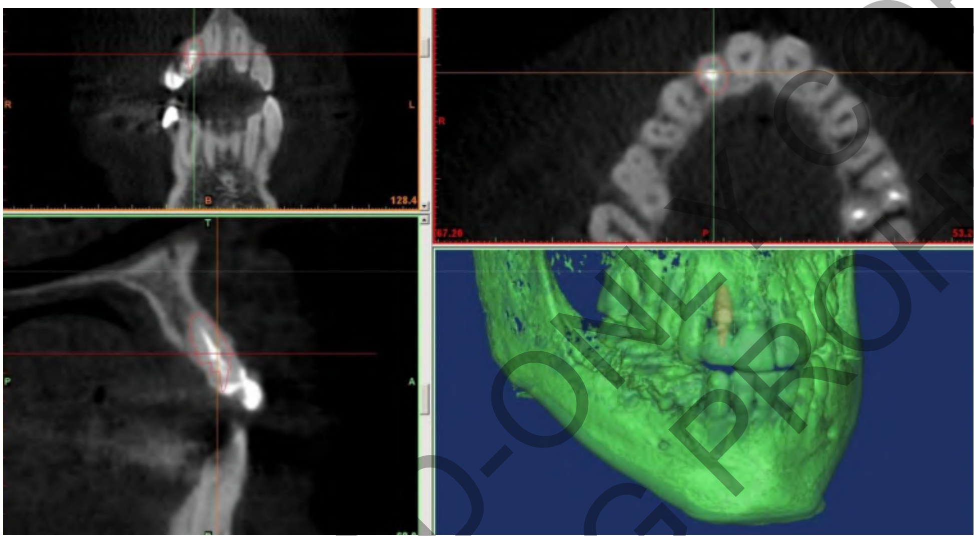

Fig. 1: 3D projection of the maxilla and the residual root. The root is isolated and the 13 project of the root analogue implant begins.

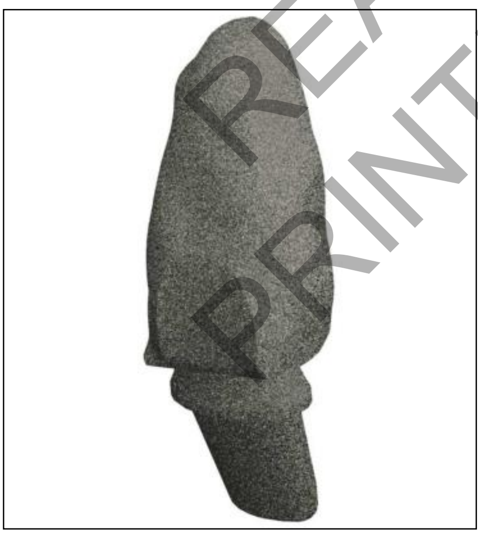

Fig. 2: The STL file of the custom-made RAI. An integral abutment has been added. The root analogue has been designed with a reduction of the diameter of the implant neck of 0.1– 0.3 mm next to the buccal cortical bone.

Fig. 3: The non-restorable maxillary lateral incisor is extracted and the DMLS RAI is placed in position.

Fig. 4: Immediately after surgery, a provisional restoration is placed on the RAI.

Fig. 5: Two weeks after surgery, the provisional restoration is in position.

Fig. 6: Three months after surgery, the peri-implant soft tissues show a good adaptation and the final metal-ceramic crown can be delivered.

Fig. 7: At the 1-year follow-up control, the prosthetic restoration shows excellent functional and esthetic integration.

sion was performed, and the non-restorable incisor was gently extracted to avoid any damage to the socket - the loss of the buccal bone wall would compromise primary stability of the RAI jeopardizing the outcome. Then the socket was carefully debrided, the RAI was gently inserted into the socket using a little percussion hammer. Primary stability was achieved, and carefully checked (Fig. 3) then sutures were positioned. The RAI was immediately provisionalized with a cemented single crown; care was taken, however, to avoid any functional contacts (Fig. 4). Oral antibiotics were prescribed, amoxicillin+clavulanic acid, 2 g/d for 6 days (Augmentin®, GlaxoSmithKline Beecham, Brentford, UK) together with analgesics, 100 mg of nimesulide (Aulin®, Roche Pharmaceutical, Basel, Switzerland) every 12 hours for 2 days. Mouth rinses with 0.12% chlorexidine (Chlorhexidine®, Oral-B, Boston, MA, USA) were prescribed daily, for 7 days. The patient was seen on a weekly basis during the first month. At 1 week, no postoperative discomfort or edema was reported, and sutures were removed. At 2 weeks, the peri-implant tissues were stable. (Fig. 5). The provisional restoration remained in situ for 3 months, then the final metal-ceramic crown was delivered (Fig. 6), and cemented with zinceugenol oxide cement (TempBond®, Kerr, Orange, CA, USA).

Results

At the 1-year follow-up, the RAI was functioning successfully: no biological complications were reported, the peri-implant tissues were mature and stable, the esthetic integration of the crown was satisfactory. The radiographic results revealed little or no peri-implant bone loss, and no soft tissue recession was present. Radiographically, the implant-crown complex had a natural appearance, close to that of a natural tooth (Fig. 7). No prosthetic complications were registered.

Discussion

Primary stability represents a challenge in fresh extraction sockets [2,3,6,7]. The fundamental pre-requisites include adequate bone quantity and quality, gentle extraction, and a careful preservation of the alveolar socket walls [2,3,6,7]. Primary stability is also related to the macroscopic features of the fixture. As primary stability is a critical factor for osseointegration and long-term implant success, the use of custom-made RAIs congruent to the individual extraction sockets may represent an interesting alternative treatment option [8,9].
The concept is not new, the Mayans used tooth-shaped shells to replace lower incisors, the Etruscans carved wood, metal, shell, and stones to form RAIs.
In 1969, the polymethacrylate RAI used by Hodosh and coll. [10] did not osseointegrate. In animal and human stud-

ies, titanium RAI showed signs of osseointegration but failure rate was high [26]. The authors speculated that perfect implant adaptation might be responsible for the failure [26]. Following single-tooth extraction, the alveolar bone generally exhibits remarkable modifications in its vertical and horizontal dimension [27-29]. A recent systematic review on clinical studies by Tan et al. (2012) has confirmed that after tooth extraction a pronounced reduction occurs at 6 months [30]. Most tooth sites in the anterior maxilla exhibit very thin buccal walls and usually undergo marked resorption following tooth extraction [28,31,32], and are prone to pressure-induced resorption. An imperfect fit of the implant might be responsible for the esthetic failure due to pressure-induced resorption [27].
Studies show the immediate insertion of zirconia RAIs with a diameter reduction in the area in contact with the buccal bone and retentions in the interdental space yield excellent functional and esthetic results [13,14,34]. Implant diameter reduction with a slice in proximity of the buccal bone may avoid pressure-induced bone loss and related esthetic failure; the retentions in the interdental space may improve primary implant stability [13,14,34].
Recently, a novel approach using titanium custom-made RAIs and CBCT and DMLS was proposed [9,15,24,25]. In this study, a customized DMLS titanium RAI was inserted into a fresh extraction socket of the anterior maxilla. The congruence between the RAI and the socket was excellent. The neck of the implant presented a diameter reduction of 0.1–0.3 mm, and a slice designed to prevent any pressure-induced bone loss in the critical buccal bone area [35]. At the 1-year follow-up, the DMLS RAI showed a satisfactory functional and esthetic integration, no bone resorption or soft tissue recession. This technique presents two possible advantages: first, the DMLS technique permits functionally graded titanium implants, with a highly porous surface and a dense core [16-23] helping to avoid any stress-shielding effect, further reducing pressure-induced bone loss [16-23]; secondly, a porous surface is obtained capable of accelerating the healing processes and promoting osseointegration [16-23].

Conclusions

Digitalization in dentistry simplifies clinical procedures and shortens treatment times. Modern CBCT acquisition and 3D image processing, combined with the DMLS processes, permit customized RAIs. In the present study, a custom-made DMLS titanium RAI was fabricated and inserted into a fresh extraction socket of the esthetic area of the anterior maxilla. At 1 year follow-up, the integration of the DMLS implant was functionally and aesthetically satisfactory, with no bone resorption or soft tissue recessions. The fabrication and placement of customized titanium RAIs may represent a new fascinating option for immediate implantation.

Riassunto

L'acquisizione della tomografia computerizzata a fascio conico (CBCT) moderna e l'elaborazione tridimensionale (3D) delle immagini, combinata con la sinterizzazione laser diretta (DMLS), consente di realizzare impianti su misura per gli impianti root-analogue (RAI).
Lo scopo di questo articolo è quello di dimostrare come la DMLS consente la produzione personalizzata di RAI in titanio, con inserimento e ripristino immediati in un alveolo di recente estrazione dentale del mascellare anteriore.
Viene creata da un DMLS personalizzato una copia perfetta RAI in titanio dell'unità radicolare necessaria per la sostituzione, e viene inserita in un alveolo di recente estrazione dentale dall'area estetica del mascellare anteriore.
Ad un follow-up di un anno l'impianto DMLS RAI ha mostrato una soddisfacente integrazione funzionale ed estetica, senza riassorbimento osseo o regressione dei tessuti molli.
In conclusione la produzione di RAI DMLS personalizzate apre nuove interessanti prospettive per l'impianto dentale immediato.

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