IDEA 2023
Finalist awarded

ACTILINK®

IMPLANTOLOGY

Plasma Activator with Electrocatalyst

plasmapp

ACTILINK®

IMPLANTOLOGY

Plasma Activator with Electrocatalyst

Table of Content

Plasma Activation for **Professional Implantology**

Faster

Cleaner

Switchable
Plasma Mode

Easy to Use

ACTILINK **Product**

Model	ACTILINK
Size (W x H x D) (unit: mm)	reborn: 170 x 345 x 266 motion: 169 x 345 x 264
Weight	6 kg
Cycle Time	Direct Mode: 80 seconds Vortex mode: 55 seconds

ART. No. **reborn: AR33PL20KE / motion: AM33PL20KE**

※ Just a different design, same functionallity

AOS 3.0 **More reliable & More economical Version**

Overwhelming Technology that never existed in the world

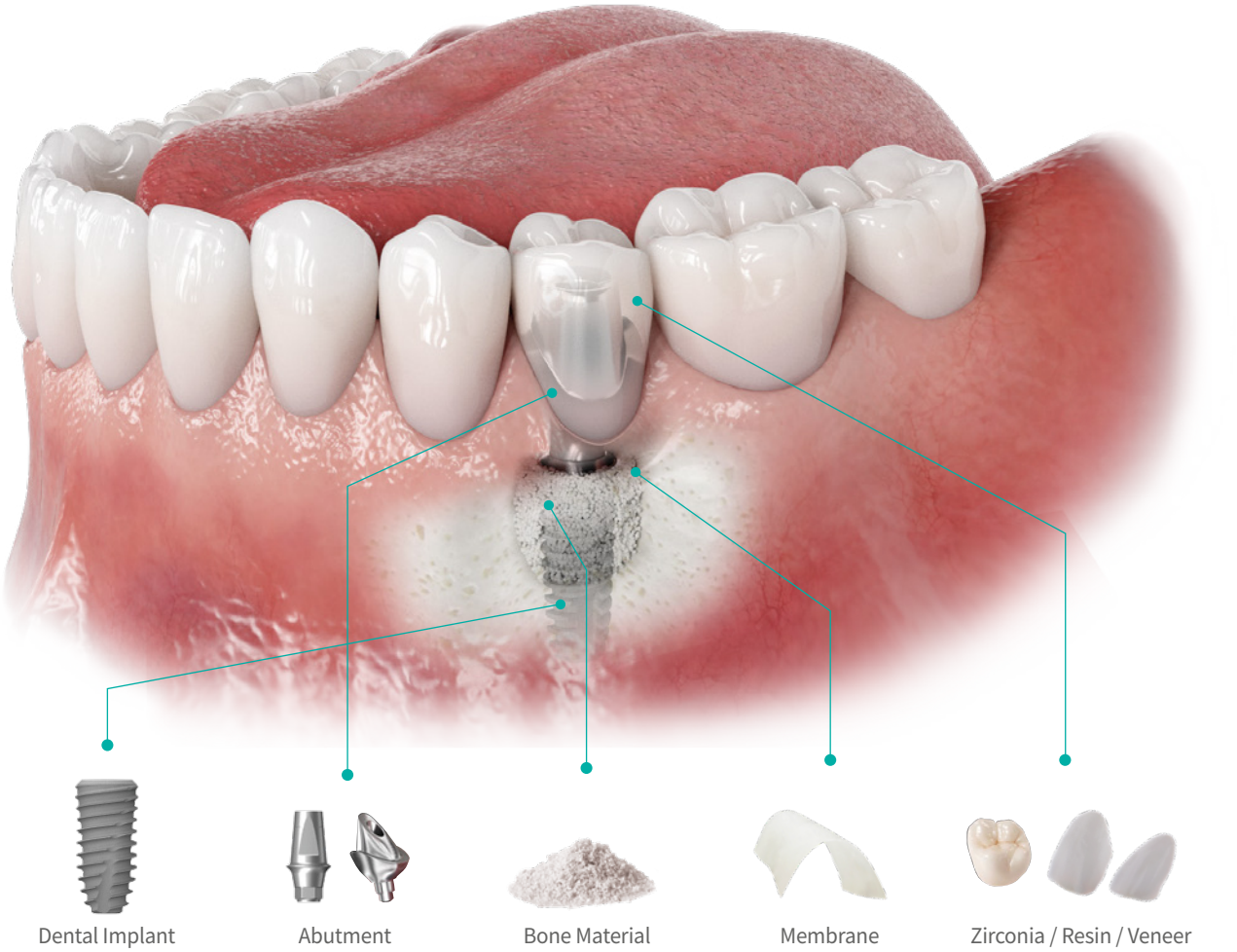
Provide Total Solutions
Great versatility
for various applicaiton

Precise Setup for Optimized Plasma Process Time
Customized process
by materials

Easy to Mode Design & Improved Reliability
Plasma Power Supply
(HVPS) 7,000 Cycles

Rejuvenate your Implant System & Dental Materials

Plasmapp ACTILINK introduces cutting-edge technology, DIRECT Plasma & VORTEX Plasma, designed to enhance the safety, performance, and flexibility of choice for all implant systems



Dental Implant | Abutment | Bone Material | Membrane | Zirconia / Resin / Veneer

Enhanced
Osseointegration

Enhanced
Tissue Integration

Enhanced
Hydrophilicity for Material Handling

Enhanced
Fibroblast Activity & Material Handling

Enhanced
Uniformity and Strength of Bonding

DIRECT PLASMA

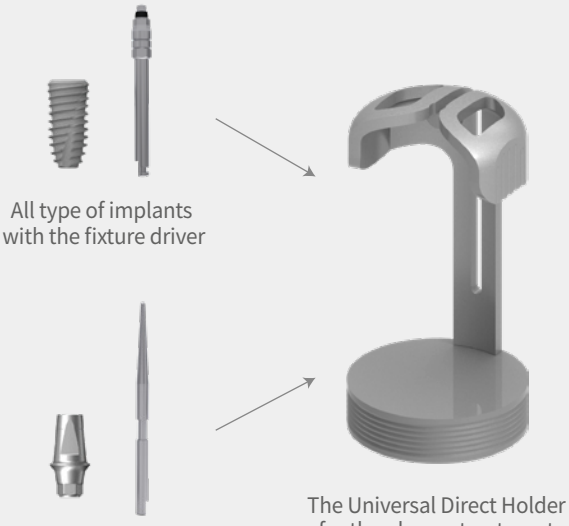
Outstanding performance for all kinds of implant system

Solution for challenging protocols of patients with short treatment time

[Open Type]

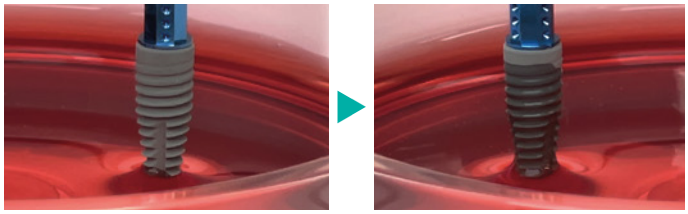
Universal Direct Holder

for all kinds of implant system



ART. No. AAP029

The DIRECT plasma mode for a more efficient and faster method of activating the implant surface



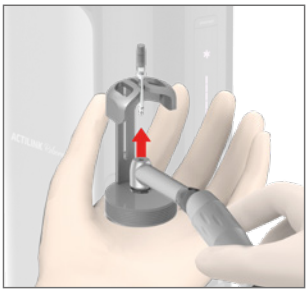
Before **After**

DIRECT plasma mode

Yellow Color LED

Press the Top button for the selection of mode
*Refer to the manual for additional information

Engage and deliver the implant instantly using the handpiece to keep it clean



VORTEX PLASMA

Designed for easy usage with a customized holder

Implant is treated inside of its own ampule

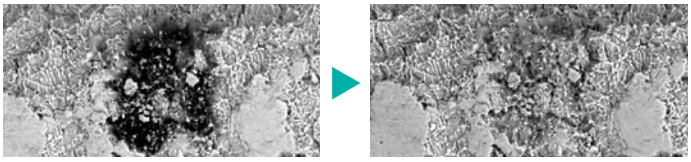
[Close Type]

Implant Vortex Holder

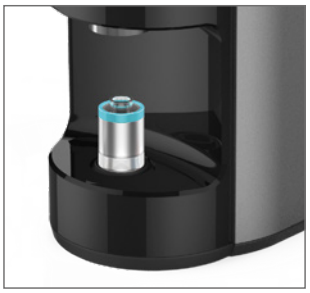
Customized for all kinds of implant brand

Library of ampules for 32 brands

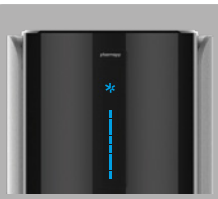
AB Dental	Cowelmedi	iRES	Osstem	Warantec
ACH Medical	Cybermed	Megagen	SIC	Withwell
Astra	Dentis	MIS	Straumann	Zimmer
BEGO	Dentium	Neobiotech	Sweden & Martina	...
Bio Horizons	Dio Implant	Nobel Biocare	Toplan	
Biotem	IBS	Oneday Biotech	TRI	



Optimized for SLA Surface, and other surfaces such as HA and RBM have also been found effective for plasma treatment.



The caps of the Ampule must be removed.
Make sure to use the correct Vortex Holder for your brand of implant ampule.



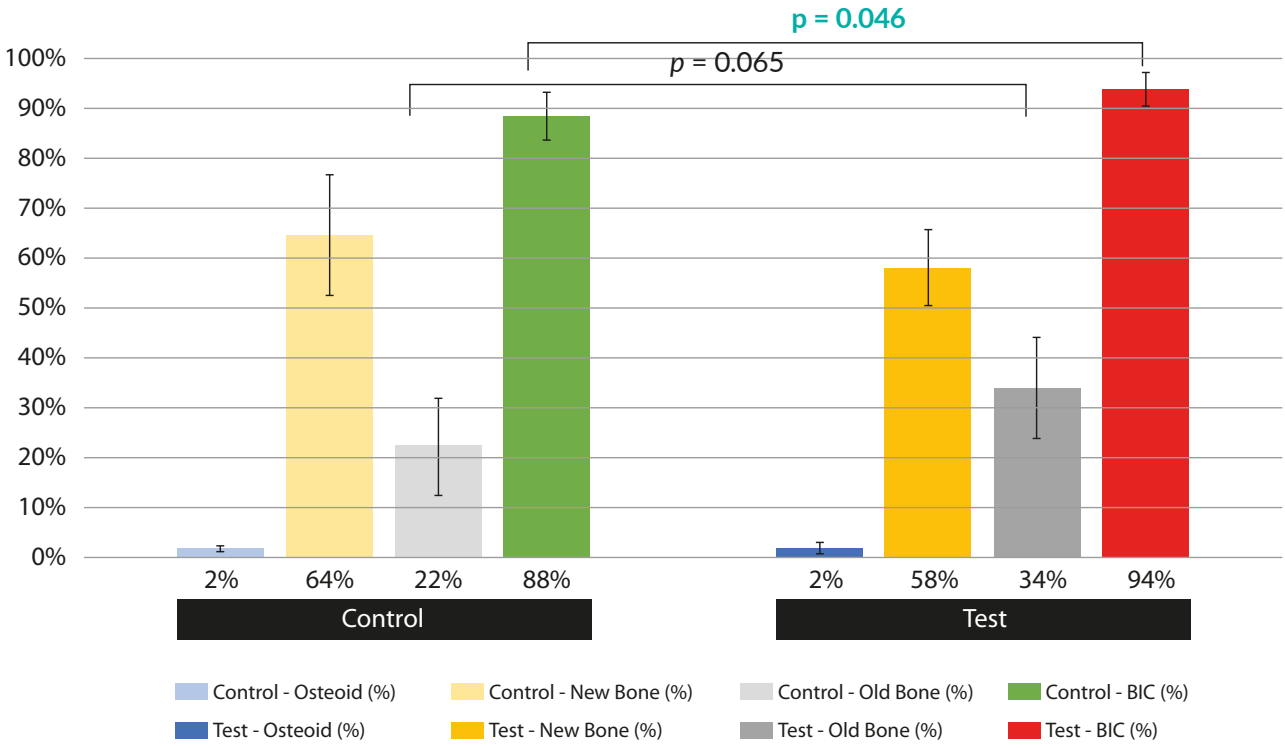
VORTEX plasma mode

Blue Color LED

Press the Top button for the selection of mode
*Refer to the manual for additional information

Pre-clinical test for improved osseointegration performance

Bone to Implant Contact (4 weeks)



Histology Figure (4 weeks)

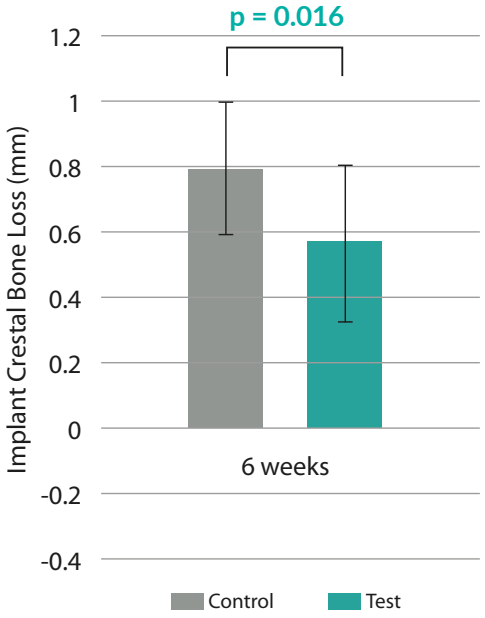
Total BIC (Bone to implant contact): **93.7%**
= Osteoid (1.8%) + New bone (58.0%) + Old bone (33.9%)

Control

After Treated

Bone Loss (6 weeks)

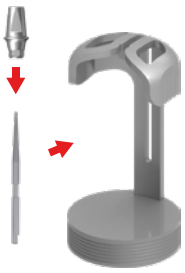
Bone loss was reduced in the Test group compared to the Control group after 6 weeks

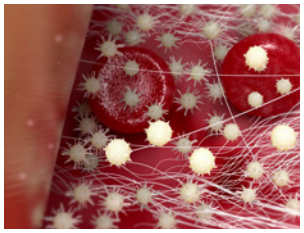


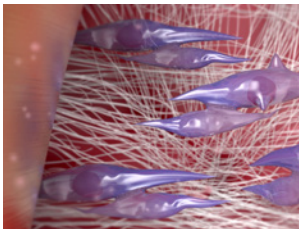
※ Comparison of Bone-to-Implant Contact results between control and plasma treated groups after 2 weeks and 4 weeks.
(T-test significant difference at 4 weeks *p < 0.05.)
※ 2023 Perio Implant Research Inc. (October 5, 2023)

Enhanced fibroblast activity test on prosthetic in titanium material

Titanium machined surface with increased hydrophilicity after plasma treatment, by improving the in-teraction with the blood clot, increases protein adsorption, such as fibronectin and vitron-ectin, with a positive effect on cellular adhesion, spreading and proliferation

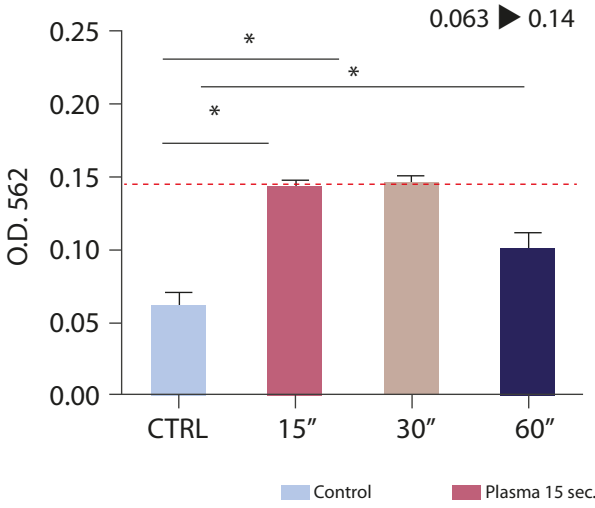






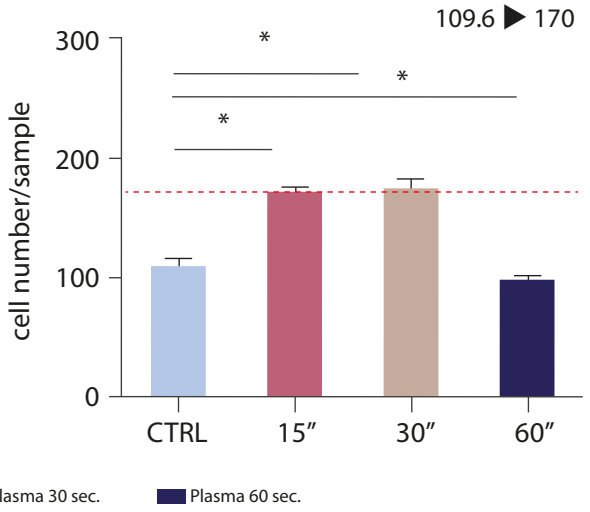
Initial protein adsorption **127% Enhanced**

0.063 ▶ 0.14

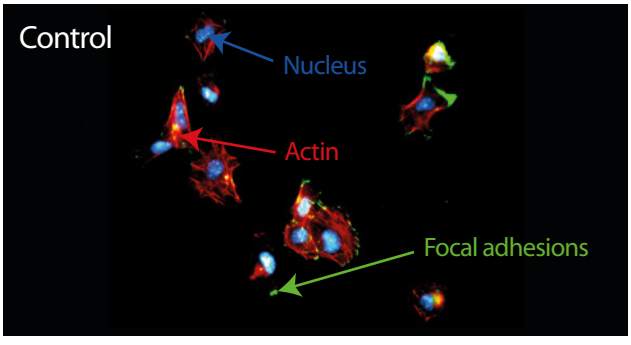


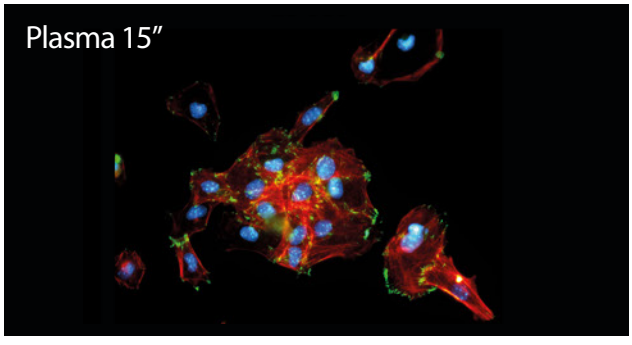
Fibroblast cell adhesion **55% Enhanced**

109.6 ▶ 170



Cell morphology





The cells were stained for the nucleus (DAPI, blue), the actin (rhodamine-phalloidin, red) and the focal adhesions (paxillin, green).

※ 2023 Dentistry Journal (November, 2023)

To meet all your needs

Better Bio-compatibility for all kinds of dental material

[Open Type]

Universal Vortex Holder

for all kinds of dental material

VORTEX Top Cover
Inner diameter: 26mm
Height: 23mm
Including permanent magnet

VORTEX Bottom Cover
Inner diameter: 26mm
Height: 13mm
Effective Volume: 7cc

Abutment

Zircornia / Resin / Veneer

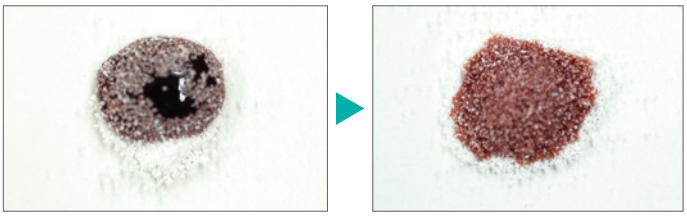
ADM / Membrane

Bone Material

Fiber Post & ETC.

ART. No. **AAP000**

Universal vortex holder enables plasma treatment with various type of dental material



Before

After

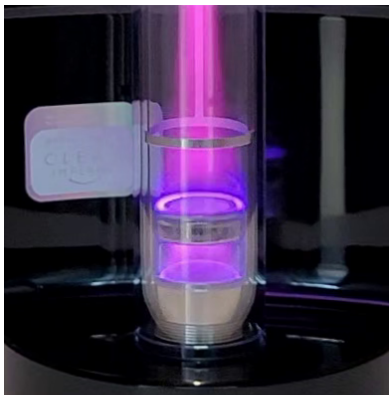
VORTEX plasma mode

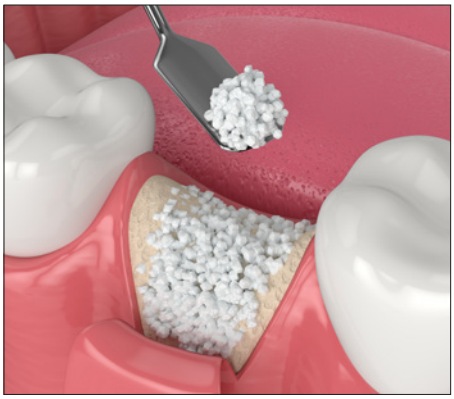
Blue Color LED

Press the Top button for the selection of mode
*Refer to the manual for additional information

Customized mounting using magnetics
Reliable plasma discharge and ACTILINK process

Enhanced hydrophilicity for bone graft material and easier handling



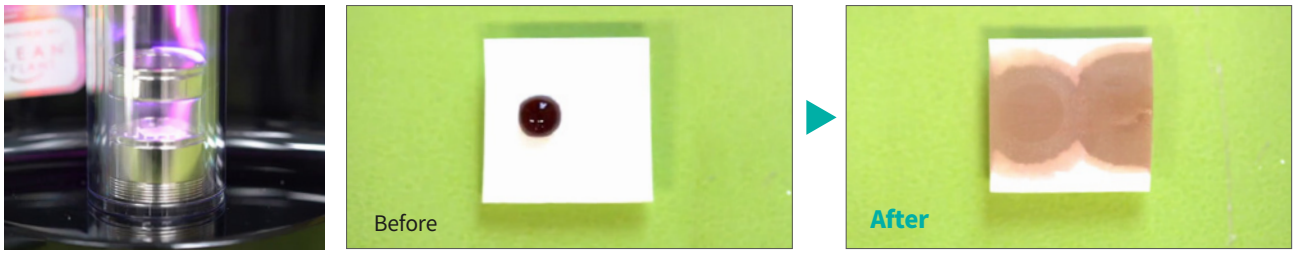


Increasing the hydrophilicity of porous bone graft materials can improve cellular adhesion and promote interaction between the implant and surrounding tissue.

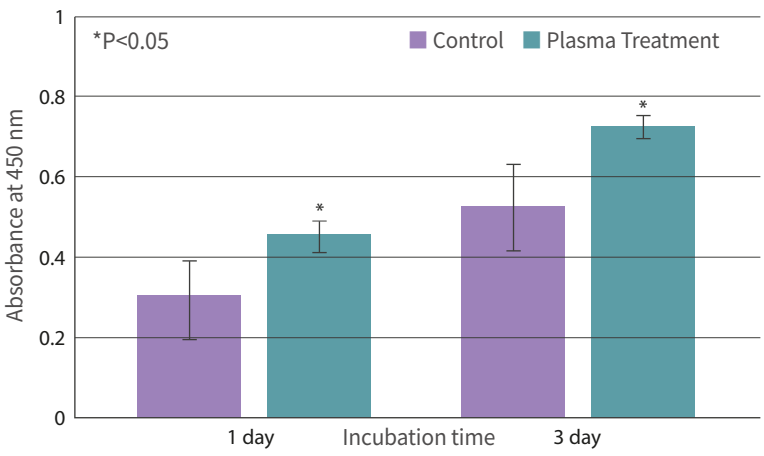
Bone material hydrophilicity test

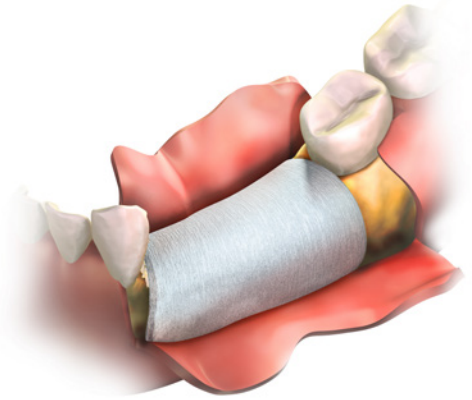
Enhanced fibroblast activity test on membrane and easier handling

Membrane hydrophilicity test



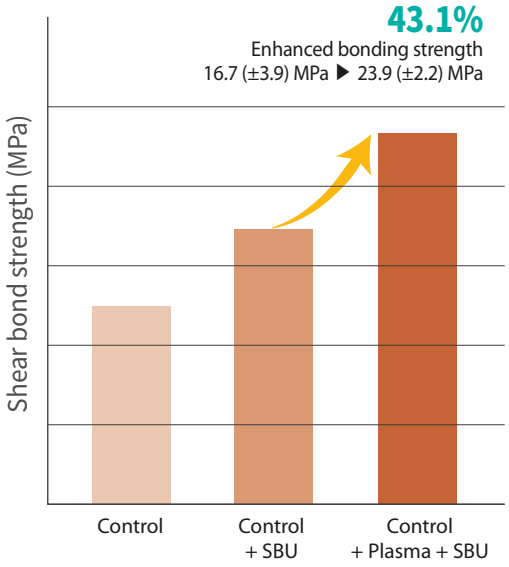
Enhanced fibroblast activity test for membrane



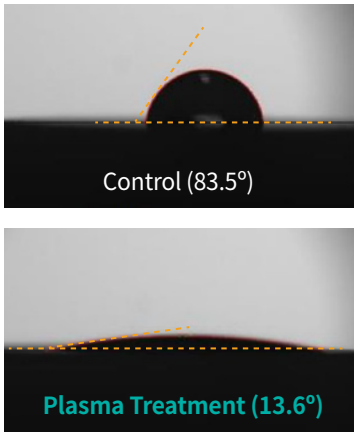


The enhanced hydrophilicity of membrane makes it easier to handle during suturing

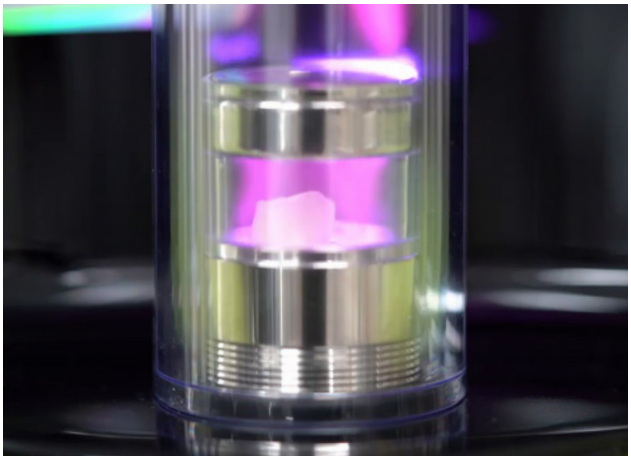
Enhanced shear boding strength for zirconia prosthetics



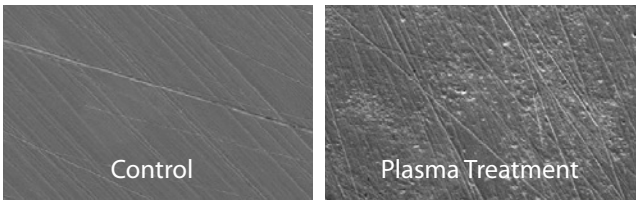
Zirconia contact angle test
(hydrophilicity enhanced)



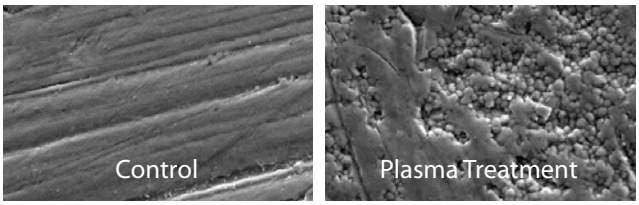
Improved hydrophilicity with final structure of roughness

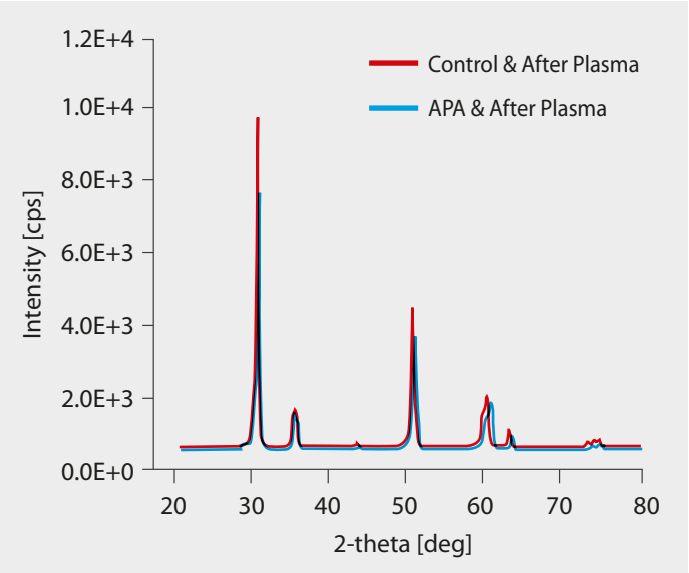


x500



x5,000





Zirconia remained unchanged after plasma treatment, and no physical damag was detected

No change in the structure of zirconia crystals under plasma treatment conditions for 5 minutes.

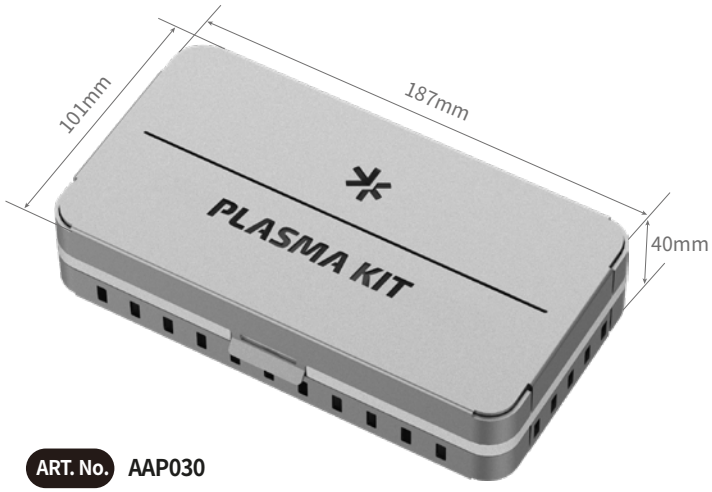
No transition to the monoclinic phase occurs due to plasma treatment.

No change in the full width at half maximum (FWHM) of the main peak, T(111) phase, after plasma treatment.
: Plasma treatment does not alter the microstructure, including crystal size.

Dedicated kit for quick and safe sterilization of holders

The Implant Vortex Holder and Universal Vortex Holder can be accommodated for a total of 4 stacks

※The holders in this Plasma Kit image is optional.
Contact us for more information about the component.



ART. No. **AAP030**

Parts can be disassembled and cleaned for next usage
※ **Plasma Sterilzerable or autoclavable**

Universal Direct Holder

Implant Vortex Holder

Universal Vortex Holder

plasmapp

Responsible for **the healthy life of humankind**

Plasmapp aims to contribute to the healthy life and happiness of humans through creative thinking and challenges beyond the boundary of thought through learning and knowledge circulation.

KAIST Launches Laboratory in 2015
2020 Selection of '**Preliminary Unicorn Company**'
2022 Certification of '**Innovative Medical Device Company**'

Globally Approved (26 FDAs)
The first small-sized plasma sterilizer clearance by US FDA

Patent Protected
Innovative Technology (144 patents)

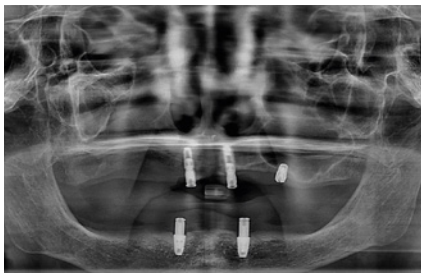
QMS Certified
(GMP, ISO 13485 and MDSAP)

Clinical Cases

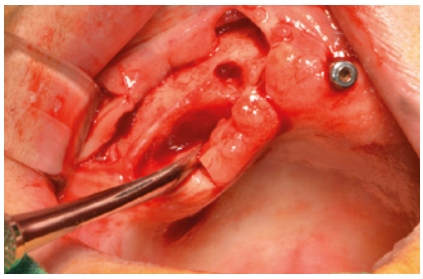
with ACTILINK activation

Implant replacement of implant failure and bone loss

Surgery by **Dr. Do-Hee Kim** Pyeonhan Dental Clinic, Korea

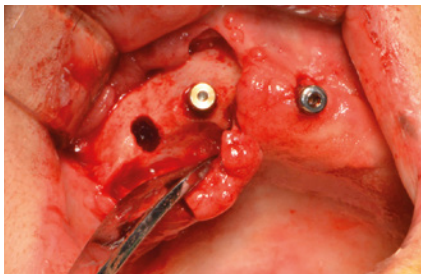


Pre-operation
Panorama view

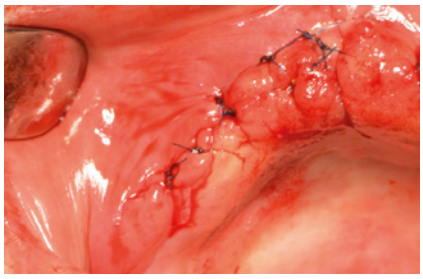


Intra-operation
Incision and flap elevation

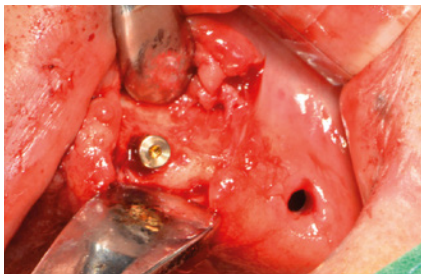
Intra-operation
Plasma treatment of fixture 12, 22



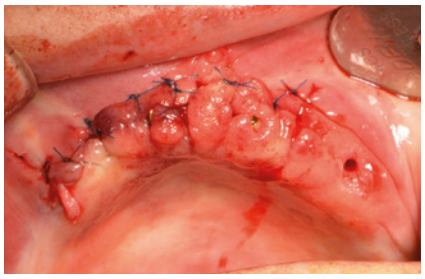
Intra-operation
Implant placement in 12
(Initial torque 45Ncm)
& cover screw connection



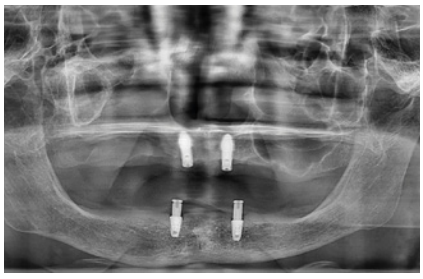
Intra-operation
Suture



Intra-operation
Implant placement in 22
(Initial torque 45Ncm)
& cover screw connection



Post-operation
suture



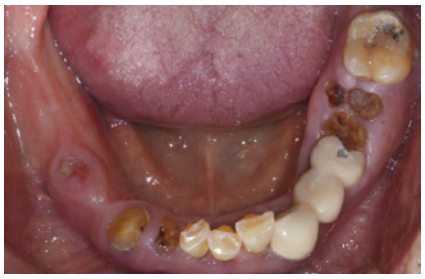
Post-operation
Panorama view

Conclusion

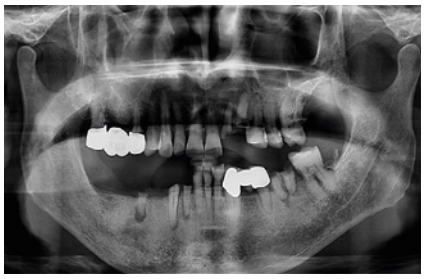
In this case, after placing #12 and #22, #12 failed while using overdenture and #22 buccal bone loss was about 4mm, so #12 and 22 were re-implanted. As an elderly female patient in her late 70s, she had already failed once, so she was very concerned about re-implanted. Plasma surface treatment was used to improve osseointegration of the implants with the existing bone. Additional implantation was attempted in #14 and #24, but in the case of #14, the bone volume was insufficient after bone leveling and implantation was not possible. In summary, #12, 22, 25 were removed and #12, 22 were plasma treated and re-implanted.

Immediate implant placement on posterior mandibular area

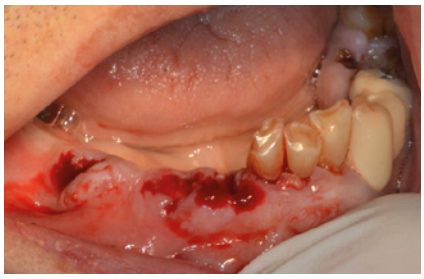
Surgery by **Dr. Do-Hee Kim** Pyeonhan Dental Clinic, Korea



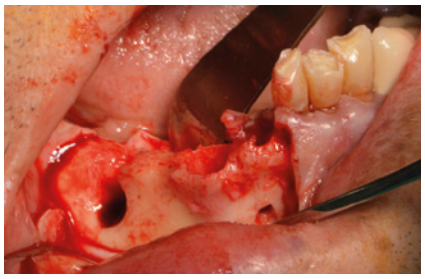
Pre-operation
Intraoral view



Pre-operation
Panorama view.
Multiple teeth abrasion and fractured

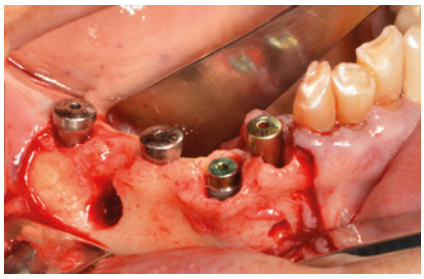


Intra-operation
Extraction of 42, 43, 45

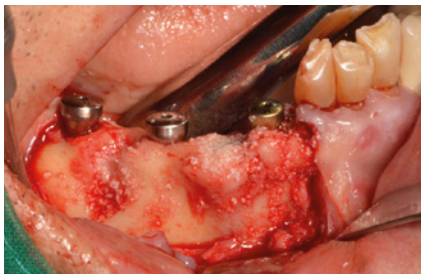


Intra-operation
Implant placement in 42, 43, 44, 46

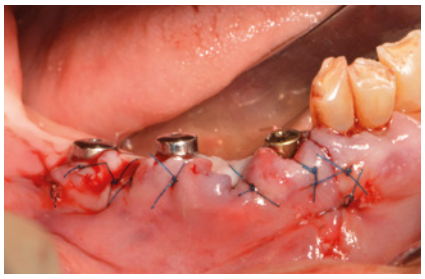
Intra-operation
Plasma treatment of fixture 44, 46



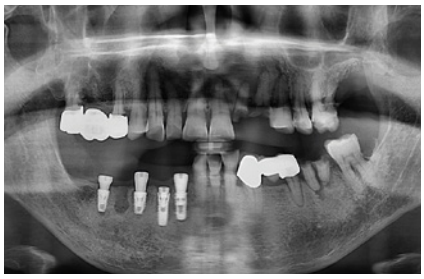
Intra-operation
Healing abutment on 42, 44, 46
and cover screw on 43



Intra-operation
Bone grafting on 42, 43, 46



Intra-operation
Suture



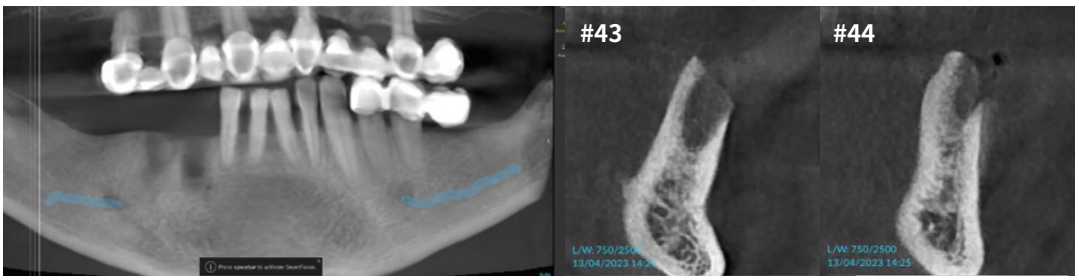
Post-operation
Panorama view

Conclusion

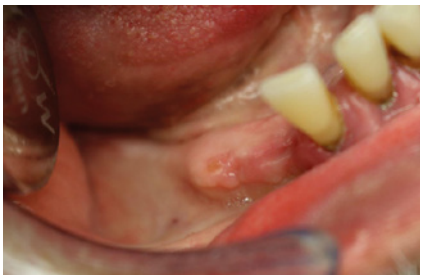
This patient had a D1 bone that was so hard that the initial drill had to be replaced at the time of surgery. Despite using a drill with good cutting power, these patients require more force than usual, and they are also a case where we have to worry about failure due to bone heating. In addition, since they have a small blood supply, the success rate is bound to decrease due to osteonecrosis around the implant, but by applying surface treatment through Plasmap's Actilink, we thought that the success rate of implant treatment could be increased by strong hydrophilicity in an environment with a relatively low blood supply.

Implant placement with simple bone grafting

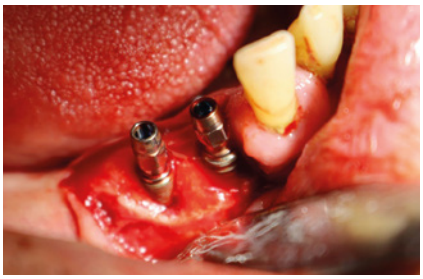
Surgery by **Dr. Kyoung-Hwan Jang** DR. ERDÉLYI ÁRPÁD FOGÁSZATI PRAXIS, Hungary



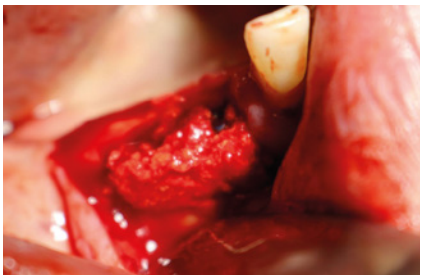
Pre-operation
Panorama view & CBCT. After 43,44 extraction, healing capacity seems inappropriate based on CT



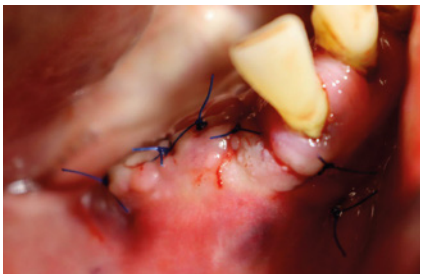
Pre-operation
Intraoral view



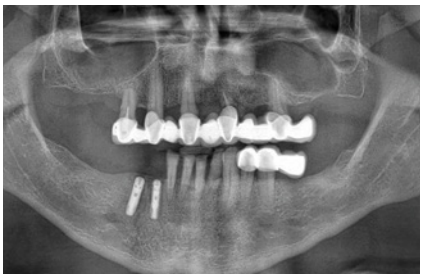
Intra-operation
Incision and Implant placement in 43, 44 (44 plasma treatment)



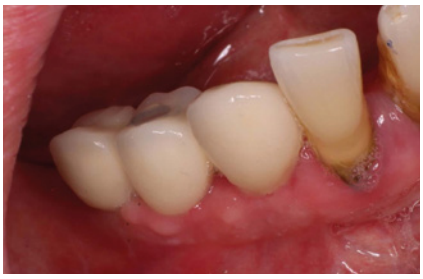
Intra-operation
Buccal Bone graft on 43, 44



Intra-operation
Suture



Post-operation
Panorama view



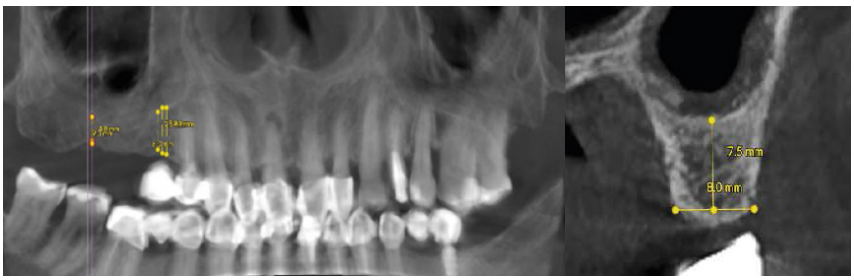
Final prosthesis
3-unit bridge 43,44,45 (45 pontic)

Conclusion

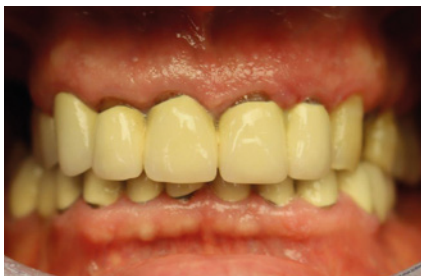
The patient had a slow healing after teeth extraction as confirmed by CT scan.
Therefore, Plasma treatment was performed to enhance bone bonding with the implant fixture.

Implant placement with crestal sinus lifting

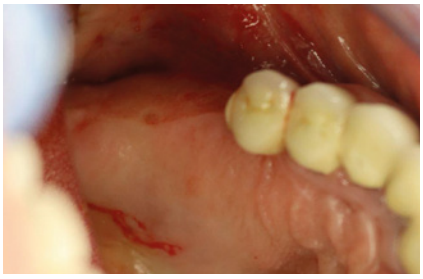
Surgery by **Dr. Kyoung-Hwan Jang** DR. ERDÉLYI ÁRPÁD FOGÁSZATI PRAXIS, Hungary



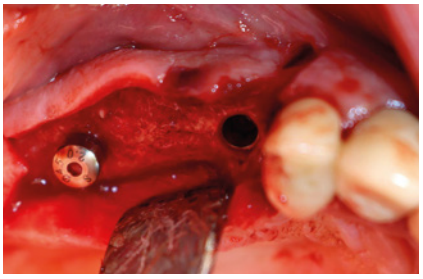
Pre-operation
Panorama view & CBCT



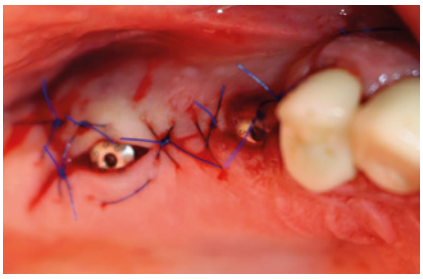
Pre-operation
Intraoral front view



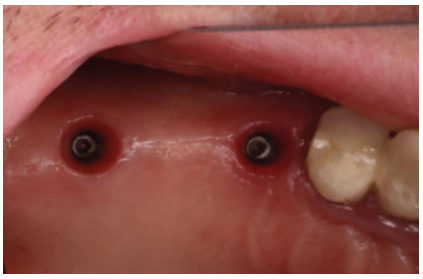
Pre-operation
Posterior occlusal view



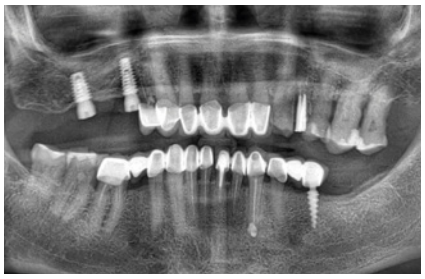
Intra-operation
Placement of 15, 17 plasma-treated implants
& healing abutment connection after crestal sinus elevation



Intra-operation
Suture



Post-operation
After healing



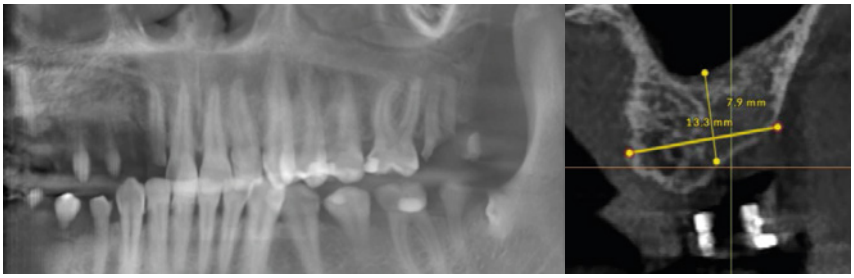
Post-operation
Panorama view

Conclusion

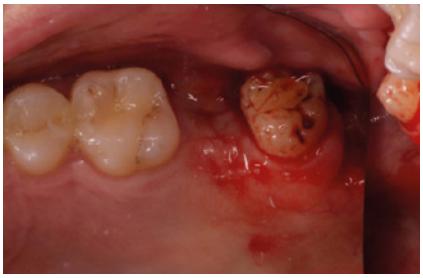
The patient had implant surgery after crestal sinus lift due to insufficient residual bone height for implant placement.
The surface of #15 & #17 implants underwent plasma treament, and the healing abutments were connected well.

Implant placement in maxillary right and immediate loading

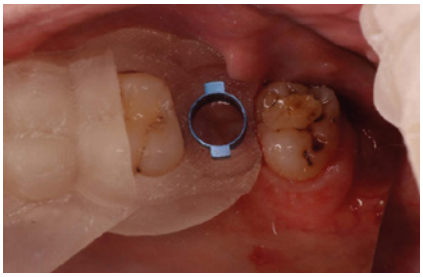
Surgery by **Dr. Kyoung-Hwan Jang** DR. ERDÉLYI ÁRPÁD FOGÁSZATI PRAXIS, Hungary



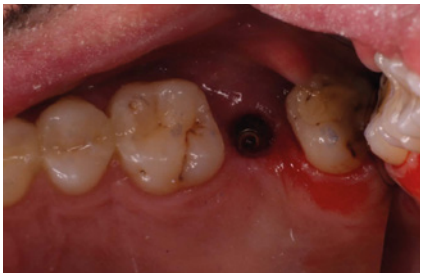
Pre-operation
Panorama view & CBCT



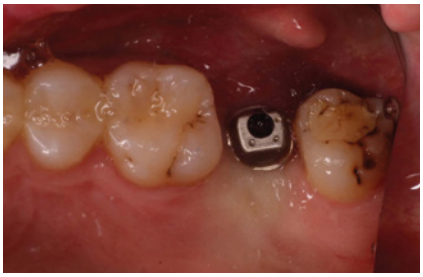
Pre-operation
Intraoral view after 27 extraction



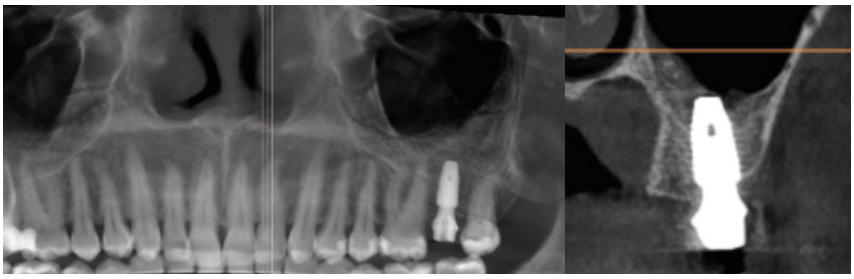
Intra-operation
Surgical guide is placed for the accurate drilling



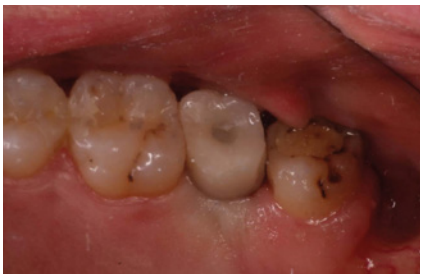
Intra-operation
Placement of plasma-treated implant (Initial torque 35Ncm) after crestal sinus elevation



Intra-operation
Customized abutment in place



Post-operation
Panorama view & CBCT



Prosthesis
Immediate loading with temporary crown

Part	Implantation	2 weeks	4 weeks
#27	80 / 71	78 / 71	80 / 71

Conclusion

The implant was placed with plasma treatment.
The ISQ was measured at 80/71 on the day of placement, so immediate loading the abutment and temporary crown. ISQ values were stable after 4 weeks.

Research Papers

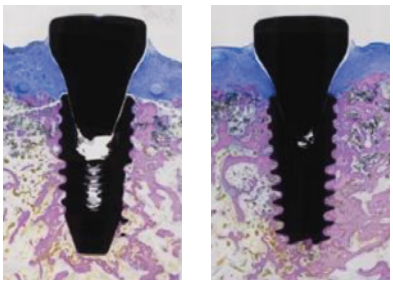
Validated ACTILINK technology for effectiveness

Gas Plasma Treatment Improves Titanium Dental Implant Osseointegration - A Preclinical In Vivo Experimental Study

Myron Nevins · Chia-Yu Chen · Stephano Parma-Benfenati · David M. Kim

Result & Discussion

In conclusion, this preclinical study underscored the potential of nonthermal plasma treatment in enhancing dental implant osseointegration. Despite a small sample size, the plasma-treated implants demonstrated superior osseointegration and reduced vertical bone loss, suggesting the potential for shorter healing times before proceeding with prosthetic loading and improved long-term stability. While further research is needed to validate and optimize this treatment, these findings highlight its promising clinical significance in potentially improving patient outcomes in dental implant therapy.



241718R (Control) *241688L (Test)*

Dental implant surface properties, such as chemical composition, electrical charge, roughness, surface energy, morphology, and wettability, play an important role in determining the cascade of biological events that allow osseointegration [4]. Dental implant surface treatments, such as plasma spray, laser treatment, acid etching, anodizing, nanoparticle depositions, and sand blasting, followed by acid etching have all allowed for faster osseointegration and reduction in loading time [4]. The results showed that plasma treatment did not significantly affect the implant torque value (ITV) and implant stability quotient (ISQ) at the time of implant insertion. We decided not to measure ISQ during the observation period in order to avoid disrupting the osseointegration process. The radiographic bone level during the early osseointegration stages (2 and 4 weeks) was comparable; however, at the 6-week mark, the plasma-treated group showed significantly higher radiographic bone levels than the non-plasma-treated control group. Our results further substantiate findings from previous in vitro studies that have reported the beneficial effects of plasma treatment on dental implants. Duske et al. reported that cold atmospheric plasma treatment reduced contact angle and supported the spreading of osteoblastic cells; furthermore, the treatment effectively removed the biofilm [28,29]. Berger et al. demonstrated that a benchtop plasma treatment at the time of implant placement could alter the surface energy of an implant without modifying the chemical composition and enhance osteoblast cell differentiation [20]. Lee et al. have conducted extensive in vitro studies, such as hydrocarbon contamination analysis, protein adsorption assay, cell proliferation assay, cell differentiation assay, and scanning electron microscope (SEM) analysis, to examine the effect of plasma treatment on dental implants [19]. With SEM analysis, there was no noticeable difference between the conditions of the sandblast large grit acid-etched surface before and after the plasma treatment in terms of cracking or corrosion sites. Their study revealed a 58% reduction of hydrocarbons, a 25% increase in protein adsorption, a 39% increase in cell attachment to the implant surface, and an 82% increase in alkaline phosphatase activity. Their results indicate that plasma treatment efficiently eliminates the hydrocarbon, enhancing protein adsorption and improving cell adhesion, proliferation, and differentiation.

	Control (Mean ± SD)	Test (Mean ± SD)	*p*-Value
Osteoid (%)			
2 weeks	2.2 ± 1.0%	3.6 ± 0.5%	0.366
4 weeks	1.7 ± 0.5%	1.8 ± 1.1%	0.853
6 weeks	1.8 ± 1.0%	1.1± 0.2%	0.224
New bone (%)			
2 weeks	57.7 ± 7.7%	62.8 ± 8.3%	0.316
4 weeks	64.4 ± 12%	58.0 ± 7.6%	0.292
6 weeks	71.4 ± 10.1%	73.4 ± 5.3%	0.914
Old bone (%)			
2 weeks	16.8 ± 10.8%	15.0 ± 7.7%	0.765
4 weeks	22.1 ± 9.7%	33.9 ± 10.1%	0.065
6 weeks	10.3 ± 4.7%	14.4 ± 6.8%	0.326
BIC (%)			
2 weeks	76.7 ± 11.0%	81.4 ± 6.9%	0.428
4 weeks	88.3 ± 4.8%	93.7 ± 3.3%	**0.046**
6 weeks	83.5 ±10.2%	88.9 ± 4.8%	0.284

Table 1. Statistical analysis demonstrating a significant difference in BIC between control and test implants at week 4.

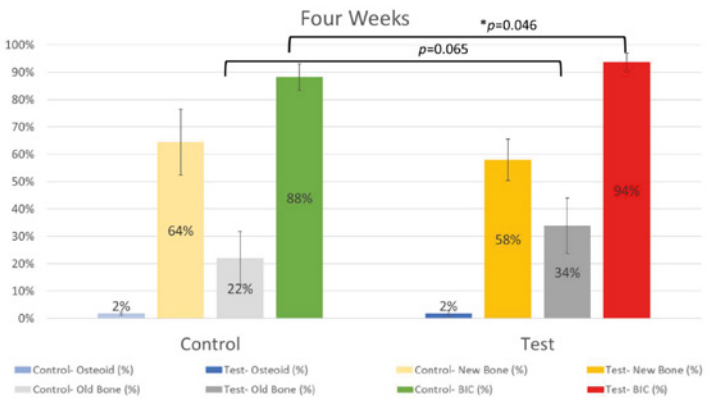


Figure 8. Representative histology images from control and test implants for each evaluation time point (2 weeks, 4 weeks, and 6 weeks). Histomorphometric analysis examined osteoid %, new bone %, old bone %, and BIC % (symbolizes statistical significance).*

Vacuum plasma treatment device to enhance fibroblast activity on machined and rough titanium surface

Canullo Luigi · Genova Tullio · Chinigò Giorgia · Roberta Iacono · Paolo Pesce · Maria Menini · Mussano Federico

Discussion

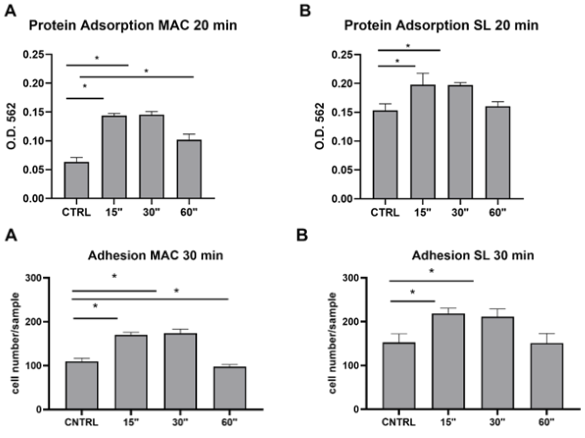
This new plasma surface treatment device generates vacuum by removing 99% of atmospheric gasses to obtain an optimized condition for discharging plasma, and this device has been used for implant fixtures to have enhanced osteoblast activity and im-proved osseointegration performance [23,24].

As already demonstrated, plasma bioactivation is able to determine an increase in the surface energy of the abutment and consequently reduce contact angle, enhance the wet-tability and make the surface more hydrophilic. Surface wettability, by improving the in-teraction with the blood clot, increases protein adsorption, such as fibronectin and vitron-ectin, with a positive effect on cellular adhesion, spreading and proliferation [18, 20,21,22].

This study also showed that fibroblast adhesion is significantly increased after Plasma treatment for 15 and 30 seconds in both samples in the early stages of wound healing (20 minutes after treatment), but also that the statistical difference with the negative control group tends to flatten out after 24 hours. The bio-efficacy of the plasma, appreciable both with the trend of protein absorption and cell adhesion, disappears after 24 h due to the saturation effect, because of the diameter of the titanium disk. The present results are con-sistent with other studies and suggest that plasma bioactivation induces a stronger fibro-blast adhesion on abutment surfaces even in the initial stages of the treatment [15, 18]. The clinical advantage of bioactivation is not only a quantitative one, related to a greater number of adherent cells, but also a qualitative one. The latter is due to the morphology of the adhered cells, as it can be seen from the SEM images, while in the control group a flat arrangement is observed, in the bioactivated samples a spread arrangement is shown.

One possible speculation is that, together with the qualitative and quantitative increase, the cell is being driven by three-dimensional geometry towards faster differentiation. This results in better cell / abutment integration, as confirmed already by Canullo et al. 2021, even in the initial phase [36].

This study further confirmed the efficacy of plasma treatment. The advantage of the plas-ma device studied in this manuscript is the reduced action time required. In the previous-ly analyzed devices, active effect of plasma was generated after 12 min and using addi-tional processing gas of argon. It is important to emphasize that the tested plasma device provides its maximum effect with the plasma treatment for 15-30 sec. Based on the find-ings from previous studies, plasma treatment can chemically modify metal surfaces [40]. Analyses, such as EDS and AFM, have demonstrated the effectiveness of plasma treat-ment in eliminating organic contaminants and oxidizing the metal surface [20,21,22, 40]. Therefore, we assumed that there is an optimal range of these cleaning and oxidation process that enhances protein adsorption and cell adhesion. As indicated by our results, exceeding this optimal threshold may result in counterproductive effects, underscoring the significance of identifying the ideal treatment conditions to attain the desired out-comes. Moreover, for the first time, a vacuum plasma treatment device not fueled by argon gas was used. Therefore, this device represents a clear practical advantage not only in terms of “clinical” time but also in terms of safety regulation. In fact, a rigid bureaucracy regulates the use of this noble gas.



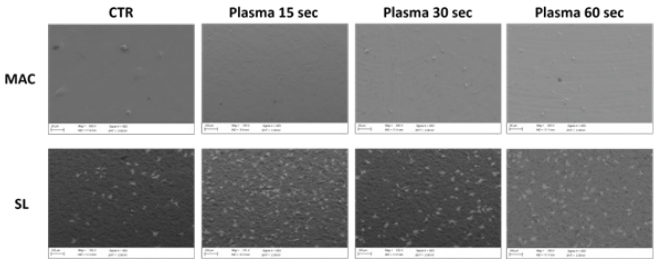


Figure 7. Representative pictures post-op conditions of discs with cell growth at different timepoints. Quantitatively significant differences can be detected between control and bio-active surfaces.

Figure 3. Protein Adsorption was evaluated on MAC and SL samples at 20 min and 4h and Plasma treatment for 15, 30 and 60 seconds. The level of protein adsorption was evaluated using BAC assay. Values represent mean ± SEM. The symbol (*) indicates the statistical significance vs CTRL surface considering a p value <0,05.

Figure 4. Cell adhesion was evaluated on MAC and SL samples at 30 min and 4h Plasma treatment for 15, 30 and 60 seconds. The level of cell adhesion was measured counting the number of adherent cells for each field. Values represent mean ± SEM. The symbol (*) indicates the statistical signifi-cance vs CTRL surface considering a p value <0,05.

Improvement of osseointegration efficacy of titanium implant through plasma surface treatment

Hyungyu Lee · Hyun Jeong Jeon · Ara Jung · Jinwoo Kim · Jun Young Kim · Seung Hun Lee · Hosu Kim · Moon Seop Yeom · Wonho Choe · Bomi Gweon · Youbong Lim

Result & Discussion

The surface of SLA and SLA+Plasma was scanned with SEM to confirm wheather plasma treatment causes any physical changes to the implant surface. As can be seen in the the 5,000× and 10,000× images in Fig. 4, there is no noticeable difference between the surface condition before and after plasma treatment. More importantly, no damage such as cracks or corrosion sites was identified on the implant surface after plasma treatment. The macro- and micro-roughness in SLA surface is important for osseointegration, and these results demonstrate that plasma treatment maintain the unique topography of the SLA imaplant surfaces without affecting the intrinsic surface of the implant (Fig. 4).

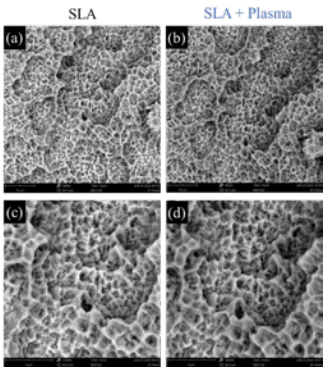


Fig. 4 The SEM images of the implant surface a, c SLA and b, d SLA+Plasma sample. (a and b are magnified by 5000×, and c and d by 10,000×)

The degree of hydrocarbon contamination was determined by X-ray photoelectron spectroscopy, with an energy peak at 285 eV representing the atomic percentage of carbon. It can be seen that the SLA and SLA+Plasma have carbon percentages of 26.2% and 11.0%, respectively, demonstrating that more than 58% of the hydrocarbons on the implant surface are eliminated by the plasma treatment as shown in Fig. 5a. In prvious study, it has been reported that protein adsorption to the implant surface increases with a decreasing number of carbon atoms on the surface, indicating a strong negative correlation with a high coefficient of determination (R2 = 0.930) between the number of carbon atoms and the amount of adsorbed protein on the implant surface. Similarly, when carbon is gradually eliminated, osteoblast adhesion grows substantially, and the amount of hydrocarbon is also known to be strongly related to cell adhesion rates. Therefore, we use proteins and cells to perform in vitro experiments to identify the effects of plasma-treated surfaces on osseointegration efficiency. Fibronectin is used in the protein adsorption experiments. When a titanium implant is placed into a bone, protein adsorption occurs on the implant surface as the first physiological phenomenon when it comes into contact with physiological fluids around the site. Among the numerous extracellular matrix (ECM) proteins, fibronectin, in particular, plays an important role in promoting cell adhesion and proliferation by providing an integrin-binding site. We compared the amount of protein adsorbed to SLA and SLA+Plasma surfaces to investigate the effects of plasma treatment on fibronectin adsorption. As shown in Fig. 5b, the amount of proteins adsorbed to the surface of the SLA and SLA+Plasma is measured to be 2,029 ± 236.4 and 2,529 ± 95.7 ng, respectively. Plasma treatment appears to increase protein adsorption to the implant surface by 24.6%. The number of cells on each implant surface is then measured using a microplate reader at a wavelength of 450 nm. As shown in Fig. 5c, the number of cells attached to the implant surface is approximately 38.5% higher in the SLA+Plasma than in the SLA immediately after the 2-hour time point. This implies that plasma treatment significantly enhances the cell adhesion efficiency. Also, it can be seen that the number of cells in the SLA+Plasma group is approximately 40.2% higher than that in the SLA group after 5 days of incubation, confirming that cells proliferate better on plasma-treated surface (Fig. 5c). ALP activity is then evaluated after 7 days of culture to assess the level of differentiation. ALP is generally used as an initial marker of osteogenic differentiation, and high ALP activity indicates that cells are more capable of differentiation and functioning as osteoblasts. The ALP activity of the SLA and SLA+Plasma groups is 1.78 ± 0.42 and 3.23 ± 1.23 unit/ml, respectively, as shown in Fig. 5d, demonstrating that ALP activity in the SLA+Plasma group is approximately 81.5% higher than that in the SLA group.

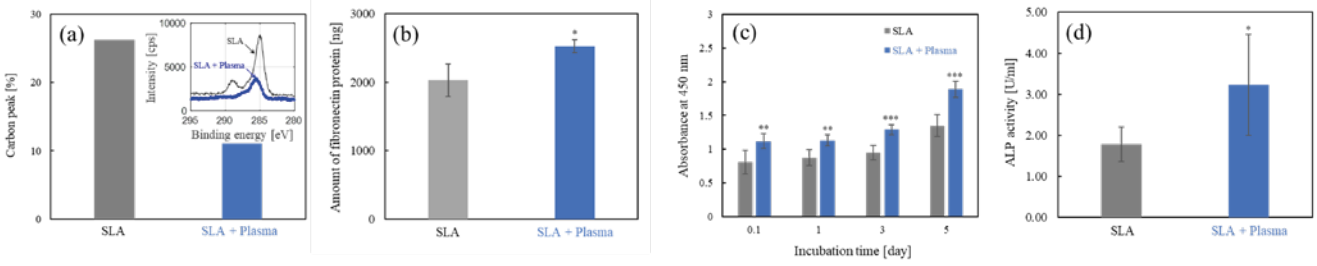


Fig. 5 Results of a XPS analysis, b protein adsorption, c cell proliferation, and d ALP activity for SLA and SLA+Plasma samples.
** P < 0.05, ** P < 0.01, and *** P < 0.001 (Unpaired student's t-test. Each SLA+Plasma data was compared to the corresponding SLA data.)*

Enhanced Osteoblast Adhesion and Proliferation on Vacuum Plasma -Treated Implant Surface

Hyun Jeong Jeon, Ara Jung, Hee Jin Kim, Jeong San Seo, Jun Young Kim, Moon Seop Yum, Bomi Gweon, and Youbong Lim

Discussion

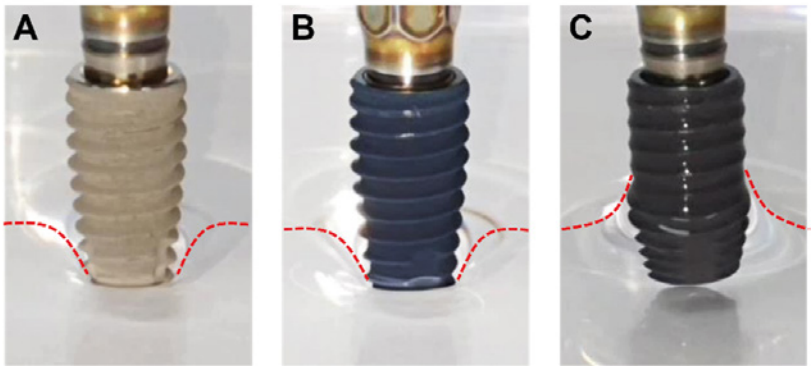
N2 plasma treatment on TiO_2 was shown to reduce Ti^{4+} to Ti^{3+} as in UV treatment, generating oxygen vacancies and leaving TiO_2 positively charged. It has also been demonstrated that air-based O2 plasma treatment forms a hydroxyl (OH) group on the TiO2 surface, which is known to improve the hydrophilicity and binding affinity with proteins.

Based on these previous studies, the increase in hydrophilicity, improvement in protein adsorption, and cell adhesion observed in our study can be considered a result of the plasma-induced chemical process on the implant surface. In our in vitro investigation, the plasma-treated implant (PCaSLA) showed significantly higher levels of protein adsorption, osteoblast adhesion, and differentiation than the non-treated implant (CaSLA). In addition, when observing the morphology of cells attached to PCaSLA, cells were more evenly and widely attached than that on CaSLA. These results are believed to be relevant to the increased hydrophilicity of the implant by the plasma. Ujino et al. have reported that plasma-induced surface modification increased hydrophilicity, cell adhesion, and further upregulated osteogenesis-related genes such as Runx2, ALP, and BMP-2. In addition, they observed twice as much calcium deposition on the plasma-treated titanium surface compared to the control, indicating a high degree of clinical relevance.

As mentioned in the Section 1, hydrocarbon-based impurities are generally known as detrimental to protein adsorption and osteoblast adhesion. Aita et al. (2009) have shown a strong negative correlation between the level of carbon and the attractiveness of protein and cells. Accordingly, they suggested that carbon removal contributed to improving bone-implant integration. Therefore, our experimental results in which plasma treatment reduced the amount of carbon on the implant surface are very encouraging. Plasma contains various high-energy species, including electrons, charged species, reactive oxygen species, metastable atoms, UV photons, etc..

Given the fact that there is no extra gas supplied to our plasma device, the main discharge gas is air. In consequence, plasma will contain oxygen-related species such as O^+, O^{2+}, O^-, and O^{3-}. In a number of investigations related to plasma cleaning, researchers have demonstrated that carbon contaminants react with these oxygen-based species and become dissociated and reduced, releasing CO_2 and H_2O. Furthermore, continuous pumping to maintain a vacuum in the package removes these by-products immediately after they are released, eliminating the possibility of re-contamination.

More importantly, all of these plasma-bioactivation effects were achieved without causing any damage to the implant's existing calcium coating or microstructure. This is crucial in applying plasma treatment to the calcium-coated implant because if the plasma treatment damages the calcium coating, the osseointegration efficiency may be impaired rather than improved. According to many previous studies, calcium coating on the implant is known to promote osseointegration. Feng et al. (2004) have demonstrated that calcium coating on the implant surface increases the adsorption of protein and improves the adhesion and proliferation of cells. They reported that the calcium coating positively charged the implant surface with Ca2+ ions, which created a favorable environment for FN and Vitronectin (VN) adsorption, leading in increased osteoblasts attachment.



(A). SLA (B). CaSLA (C) PCaSLA

Product Order Code

Product Unit	Art. No.	Weight	Unit Size	ETC
ACTILINK reborn	AR33PL20KE	6 kg	170 x 345 x 266 mm	Just a different design, same functionallity
ACTILINK motion	AM33PL20KE	6 kg	169 x 345 x 264 mm	

Universal Holder	Art. No.	Indications	ETC
Universal Direct Holder (UDH)	AAP029	Fixture, Fixture Driver	
Universal Vortex Holder (UVH)	AAP000	Dental Materials	

Implant Vortex Holder

Brands	Art. No.	Brands	Art. No.
AB Dental	AAP019	MIS	AAP020
ACH Medical	AAP023	Neobiotech	AAP006
Astra	AAP025	Nobel Biocare	AAP028
BEGO	AAP015	Oneday Biotech	AAP010
Bio Horizons	AAP027	Osstem	AAP002
Biotem	AAP003	SIC	AAP013
Cowelmedi	AAP021	Straumann	AAP014
Cybermed	AAP012	Sweden & Martina	AAP026
Dentis	AAP005	Toplan	AAP009
Dentium	AAP004	TRI	AAP016
Dio Implant	AAP007	Warantec	AAP022
IBS	AAP024	Withwell	AAP008
iRES	AAP018	Zimmer	AAP017
Megagen	AAP011		

※ Customized for implant brand

Plasma Kit	Art. No.	Indications	ETC
Plasma Kit	AAP030	Kit for Sterilization holders	

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Plasma Activator with Electrocatalyst

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