A novel technique of Er:YAG laser-enhanced early implant stability

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_Introduction

Over the years, developments in implant dentistry have concentrated on implant design and surface treatment of titanium,[1–11] and successful osseointegration[12] is now considered the minimum standard for all implants.

To avoid bone necrosis, preparation of the osteotomy site is commonly achieved with a series of drills and copious water irrigation. Studies show that erbium lasers with water spray can also be used to prepare the site.[13–17] However, little attention has been paid to the possibilities of laser conditioning after drill preparation of the implant site.

The Er:YAG laser has a wavelength of 2,940 nm. It falls within the mid-infra-red region (invisible to the human eye) and is well absorbed by water molecules and hydroxyapatite. Since water is one of the main constituents of all oral hard and soft tissues, the Er:YAG laser is therefore used in the ablation of tooth, bone and dental soft tissue.[18–33]

Er:YAG laser osteotomy and drill osteotomy have been compared in animal studies.[16, 17, 34, 35] In these investigations, laser osteotomy yielded comparable or better results than drill osteotomy in terms of bone healing, and some of these studies[14, 16, 35] showed favourable laser results for bone-to-implant contact. Romanos et al.[13] demonstrate that Er:YAG laser irradiation appears to stimulate the secretion of platelet-derived growth factor when preparing osteotomy sites in a rat model. The study postulates that laser irradiation could improve the healing of those sites. Aleksic et al.[36] demonstrate the low-level laser effect of Er:YAG laser irradiation with the enhancement of osteoblast proliferation.

_Objective

The authors thus instituted a study to investigate the possibility of using an Er:YAG laser to condition an osteotomy site prepared according to a standard drilling sequence (SDS). They utilised a newly designed tip, performed a simple in vitro experiment, and then proceeded to test the technique with two clinical cases. The aim of this study was to compare the stability values of implant placement with and without Er:YAG laser conditioning of the bone surface following an SDS. The maxillary region was chosen for both patients.

Fig. 1_IO360 tip. (Courtesy of elexxion AG)
Fig. 2_Representation of the beam profile of the IO360 tip at 1 W emission. (Courtesy of elexxion AG)
Fig. 3_SEM image of sample 1, the SDS-prepared site, showing smear layer in bovine bone.

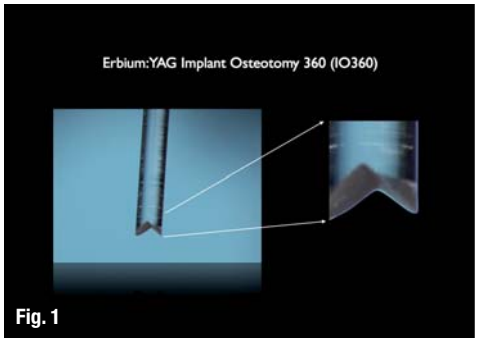


Fig. 1

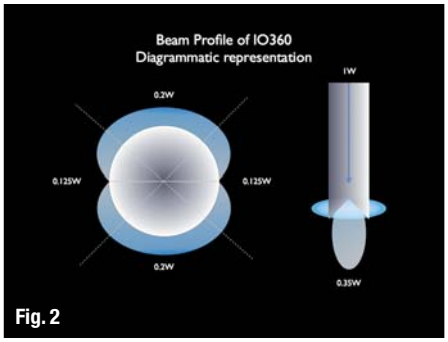


Fig. 2

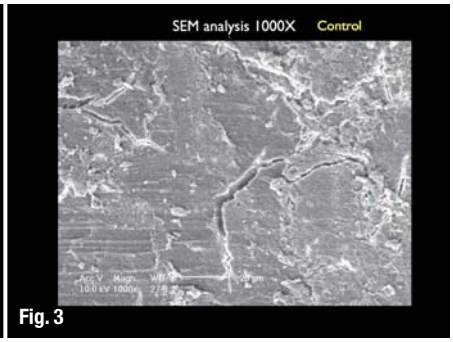


Fig. 3

_Materials and methods

Tip design

A modified wedge-shaped design, 1,200 m diameter I0360 sapphire tip was used (elexxion AG; Fig. 1). A 1 W emission of Er:YAG laser energy was analysed. The beam profile (Fig. 2) demonstrates both side- and end-firing components, although the power is not evenly dispersed. Ideally, the tip should provide an even 360-degree emission to allow complete irradiation of the osseous surface, but such a tip is not currently available from the company.

In vitro experiment

Three samples of bovine bone were used. Sample 1 was prepared according to an SDS to produce an osteotomy site (4 mm x 9 mm), and served as the control. Sample 2 was prepared by Er:YAG laser (elexxion Duros) using a 1,000 µm conventional tip with parameters of 200 mJ, 10 Hz, 2 W, 100 µs pulse duration, with water spray, irradiated for approximately 15 minutes. Sample 3 was prepared according to an SDS, similar to sample 1, followed by Er:YAG irradiation with parameters of 100 mJ, 20 Hz, 2 W, 100 µs pulse duration, with water spray, and with a vertical movement of the I0360 tip along the entire length of the site for 30 seconds. Scanning electron microscope images of the samples were taken at 1,000x magnification by Prof. W.K. Leung at the University of Hong Kong (Figs. 3–5).

_Clinical cases

Two patients were selected for this pilot study, and each was to have four implants (BioHorizons) placed in the maxillary posterior region. Osteotomies were prepared according to an SDS. One site was used as a control and the other three sites were conditioned according to the same Er:YAG laser protocol described above for sample 3 (100 mJ, 20 Hz, 2 W, 100 µs pulse duration, with water spray). The authors have named their technique the Laser-enhanced Early Implant Stability Technique (LEIST), which uses two different movements for conditioning.

The first technique, termed LEIST-v (Fig. 6), entails a 15-second vertical withdrawal movement of the I0360 tip, placed in the centre of the osteotomy site, starting 1 mm above the apical floor and finishing at the ridge surface of the site. Then the tip is rotated one-quarter turn, placed 1 mm above the apical floor, and again withdrawn vertically over a 15-second period.

The other technique, termed LEIST-s (Fig. 7), entails a spiral withdrawal movement of the I0360 tip, starting 1 mm away from the apical floor and finishing at the ridge surface of the site. As the tip is withdrawn, it passes very close to the wall of the preparation, but does not touch it. The movement takes 30 seconds.

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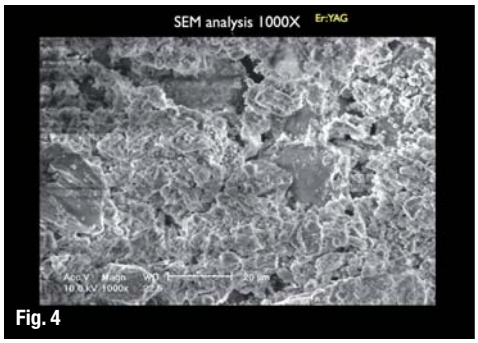
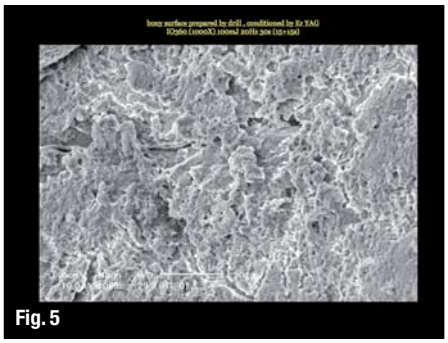


Fig. 4


Fig. 5

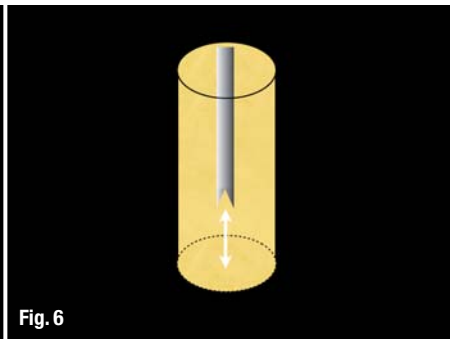

Fig. 6

Fig. 4_SEM image of sample 2, the Er:YAG laser-prepared site with conventional tip, showing minimal smear layer.
Fig. 5_SEM image of sample 3, the SDS-prepared site followed by Er:YAG laser irradiation using the I0360 tip, showing minimal smear layer.
Fig. 6_Diagram of the LEIST-v withdrawal movement of the I0360 tip.

Implant Stability Quotient (ISQ) values were recorded immediately after implant placement and subsequently at one-week intervals for 12 weeks, using the Osstell Mentor. This instrument measures resistance to lateral movement of the implant by using resonance frequency analysis, which employs the principles of a tuning fork. The stiffer the interface between the bone and implant, the higher the resultant frequency, which is converted into a number from 1 to 100 (ISQ value). The higher the stability, the larger the ISQ value. This type of device has a mean ISQ value in the range of 60 to 75.[37] As shown in Figure 8, initial mechanical stability is supplemented and then replaced by biological stability as osseointegration progresses.

Case I

The first patient was a 57-year-old male patient with a long-standing history of diabetes and heart disease. He had been taking various medications including aspirin, metformin HCl, simvastatin, metoprolol and gliclazide for the past ten years. He presented with a type 3 bone quality, which is described as thin cortical bone with underlying dense trabecular bone.[38] All of the implant fixtures were internal hex and the implant for site #27 also had the Laser-Lok feature, which is the manufacturer's proprietary implant surface treatment. Site #27 was prepared according to an SDS and LEIST-s, and an implant of 5.8 mm x 9 mm was placed. Site #26 was prepared according to an SDS and LEIST-v, and an implant of 4.0 mm x 10.5 mm was placed. Site #14 was prepared according to an SDS and LEIST-v, and an implant of 4.0 mm x 12 mm was placed. Site #15 was prepared according to an SDS only, and an implant of 4 mm x 10.5 mm was placed.

Figure 9 shows a graphic representation of the ISQ values. Implant #15, the control, showed a decrease in ISQ value from week 2 but gradually returned to initial stability at week 9. Implants #14 and 26, conditioned with LEIST-v, showed a very small decrease in ISQ value. Unlike other sites, implant #27, conditioned with LEIST-s, demonstrated an increase in ISQ value from week 1. The actual numerical readings from the device are given in Figure 10.

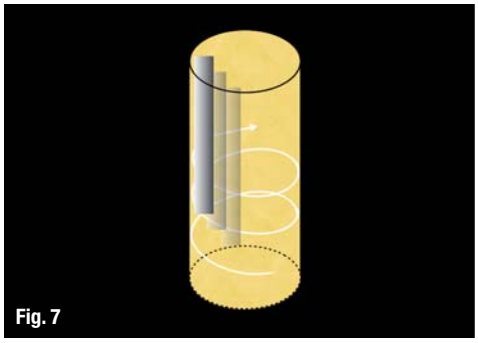
Case II

The second patient was a 69-year-old male patient with a non-contributory medical history who also had a type 3 bone quality. However, because of the location of the maxillary sinuses, three of the four sites required sinus floor elevation by osteotome. All of the implant fixtures were internal hex with Laser-Lok.

Site #27 was prepared through sinus elevation, an SDS and LEIST-s, and an implant of 5.8 mm x 7.5 mm was placed. Site #26 was prepared through sinus elevation, an SDS and LEIST-s, and an implant of 4.5 mm x 7.5 mm implant was placed. Site #15 was prepared according to an SDS and LEIST-v, and an implant of 4.5 mm x 7.5 mm was placed. Site #17 was prepared through sinus elevation and an SDS, and an implant of 5.8 mm x 7.5 mm was placed. This also served as the control.

Figure 11 shows a graphic representation of the ISQ values. Implant #17, the control, showed a 20% increase from the initial ISQ value. Implant #26, conditioned with LEIST-v, maintained an ISQ value above initial stability throughout the period. Implant #27 showed a minimal dip in ISQ value between weeks 2 and

Fig. 7_Diagram of the LEIST-s withdrawal movement of the I0360 tip.
Fig. 8_Graphic representation of ISQ values over time as osseointegration progresses. Note the initial decrease in stability, followed by an increase as the implant becomes biologically stable. (Courtesy of Osstell AB)
Fig. 9_Graphic plot of the ISQ values of each implant in Case I over a 12-week period.


Fig. 7

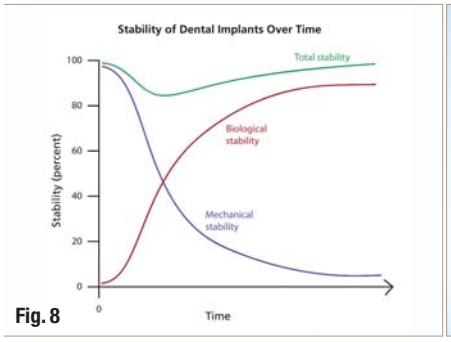


Fig. 8

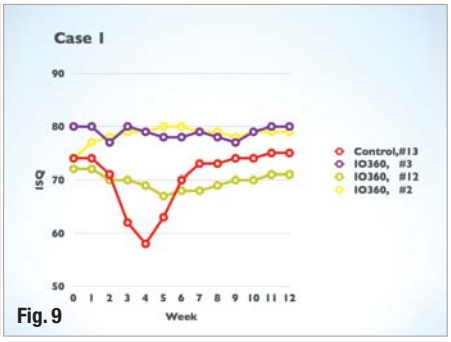


Fig. 9

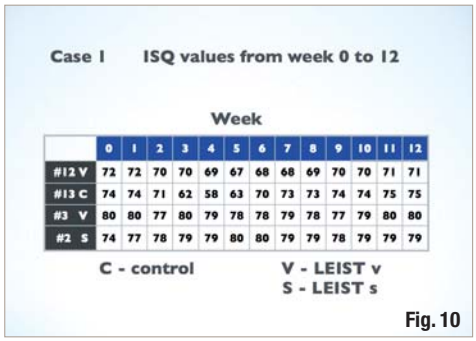


Fig. 10

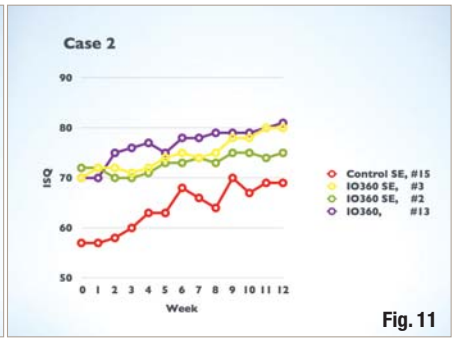


Fig. 11

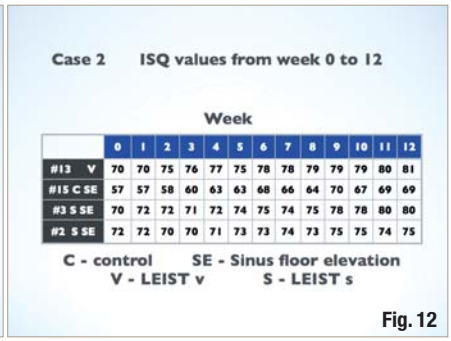


Fig. 12

4, but had recovered by week 5. Implant #15, conditioned with LEIST-v, but without sinus elevation achieved a 10 % steady rise in ISQ value by week 4, while implants #26 and 27 required nine weeks or more to reach the 10% increase in ISQ value. The actual numerical readings from the device are given in Figure 12.

_Discussion

In Case I, the control showed an expected ISQ progression with a decrease in week 2 and a re-establishment of initial stability by week 9. The 20 % drop in ISQ value was most severe at week 4, which may be related to the patient's diabetic condition. Implants conditioned with LEIST-v did not show a significant drop in ISQ value, and the LEIST-s-treated site showed a constant rise in ISQ value from the first day.

In Case II, the control started with an ISQ value of 57 at week 1 and the stability gradually increased by 20 % over six weeks. Implant #26 showed an immediate increase in ISQ value, while implant #27 showed a 3 % dip at week 2 and returned to above the initial ISQ value at week 5. Lai et al.[39] reported good initial primary stability with sinus floor elevation and a decrease in stability between weeks 2 and 6, but ultimately a high stability at week 20. The authors had similar but slightly higher values in their smaller study.

Barewal et al.[40] found that the greatest change in stability was between weeks 3 and 10. The control in Case I showed similar findings, but the sites conditioned with LEIST showed very small drops in ISQ value between weeks 3 and 10 or immediate increases in ISQ value. Bornstein et al.[41] demonstrated successful early loading with provisional prostheses 21 days after implant placement using modified-surface implants. The authors would be interested to see whether adding the LEIST protocol to these modified-surface implants could achieve any improvement in stability and early loading.

_Conclusion

The results of this very small clinical study indicate that the Er:YAG laser with a special tip design and the LEIST protocol could improve the early stability of implants. The ISQ results are promising but not statistically significant. Animal and histological studies with this technique will be the next step to confirming the progressive level of osseointegration, and more clinical cases utilising LEIST are underway.

_Acknowledgements

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_Disclosures

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Fig. 10_Numerical values of each implant in Case I over a 12-week period.
Fig. 11_Graphic plot of the ISQ values of each implant in Case II over a 12-week period.
Fig. 12_Numerical values of each implant in Case II over a 12-week period.