Evaluation Study

CONE MORSE IMPLANT-ABUTMENT INTERFACE BEFORE AND AFTER CYCLIC LOAD: EVALUATION UNDER 3-D X-RAY MICROTOMOGRAPHY

A. Scarano[1*], R. Pecci[2], S.A. Gehrke[3,4], C Bugea[1], F Lorusso[1], and S.R. Tari[1]

[1]Department of Innovative Technologies in Medicine and Dentistry, University of Chieti-Pescara, Italy;
[2]Dipartimento di Tecnologie e Salute, Istituto Superiore di Sanità, Rome, Italy;
[3]Department of Research, Bioface/PgO/UCAM, Montevideo, Uruguay;
[4]Department of Biotechnology, Universidad Católica de Murcia (UCAM), Murcia, Spain

**Correspondence to*:
Antonio Scarano, DDS,
Department of Innovative Technology in Medicine and Dentistry,
University of Chieti-Pescara,
Via dei Vestini 31,
66100 Chieti, Italy
e-mail: ascarano@unich.it

ABSTRACT

Currently, implant failures are mainly due to overload and bacterial infection of the peri-implant tissues. The internal conical implant-abutment connection is mechanically more stable and tight compared to flat-to-flat connections or tube-in-tube connections and is able to provide a better seal. The aim of this paper was to evaluate, with X-ray 3-D microtomography, cone morse implant-abutment contact surfaces before and after cyclic loading. A total of 10 implants were used in this *in vitro* study. The implants presented a screw-retained cone morse taper that was internally connected. No statistically significant differences were found in the dimension of the microgap before and after cyclic loading (P= 0.17). In all cone morse connection samples, no abutment-fixture movement was recordable. In conclusion, the cone morse taper internal connection can resist cyclic load without creating spaces between the abutment and implant.

KEYWORDS: *crestal bone remodeling micro gap, bacterial leakage, implant-abutment connections, X-ray microtomography*

INTRODUCTION

Dental implant systems using screw-retained abutments have been clinically used for many decades, and their long-term success is well documented (1-3). A problem associated with this type of implant-abutment connection is the loosening and the screws fracturing. Screw loosening could be also an indication of an inadequate biomechanical design of the prosthetic reconstructions and/or occlusal overloading. It has also been reported that, with screw-retained abutments, the abutment loosening occurs frequently (4, 5).

Loosened abutment screws and prosthesis screws are often found at yearly clinical examinations. Loosened screws may cause costly complications, such as screws and framework fractures (6). The problem of the micro gap between the implant and abutment is biological and mechanic. The biological issue is related to the presence of bacteria that have been found in the apical portion of the abutment screw (7, 8), and this fact, *in vivo*, could produce a bacterial reservoir that could interfere with the long-term health of the peri-implant tissues (8-32). The mechanical problem of the micro gap is related to

Received: 24 September 2022
Accepted: 28 October 2022

micromovements and possible loosening or fracture of screw-retained abutments (33-36). The internal conical implant-abutment connection is mechanically more stable and tight than flat-to-flat connections or tube-in-tube connections(17, 37) and able to provide a better seal (14-16, 25-27).

The aim of this paper was to evaluate, with X-ray 3-D microtomography, cone morse implant-abutment contact surfaces before and after cyclic load.

MATERIALS AND METHODS

A total of 10 4 mm x 13 mm implants were used in this in vitro study (Isomed, DUE CARRARE (PD), Italy). The implants presented a screwed connection with a cone morse interface. All abutments were coupled according to the recommended torque values.

Specimen processing

Each sample underwent five X-ray microtomography consecutive acquisitions by Skyscan 1072 (SkyScan, Kartuizersweg 3B, 2550 Kontich, Belgium) to measure implant-abutment contact areas and to detect the possible presence of microgaps over and along the whole interface. This innovative investigation technique has made it possible to assess the perfection of connection sealing in a non-destructive, non-invasive, and three-dimensional way (11, 12). All implants have been resin-embedded vertically to avoid motion artifacts within a cylinder-shaped mold. The same acquisition parameters adopted for all samples are as follows:

1. rotation step= 0.45°,
2. total rotation angle = 180°,
3. power source 100 KV/98 micro A,
4. filter thickness 1mm (Al)
5. magnification at x30 and cross-section pixel size of 9.77mm.

All images obtained have been processed by a dedicated reconstruction software (CTan), able to reproduce the exact 3D model of each examined implant.

Mechanical test

The samples were fixed by an acrylic self-curing resin to the aluminum sample holder with the major axis perpendicular to the shelf.

The loading force was applied to the abutment. The customized jig was designed to hold the implant, and the distance was 3 mm from the implant platform to the exposed position of the implant. The distance of 3 mm was chosen to represent the worst case in bone retraction (38, 39). The load was applied to the abutment at an angle of 30°C, and the distance was 11 mm from the center of the hemisphere to the exposed position of the implant. Then, each sample was loaded in a cyclic loading mode with a Lloyd 30K universal testing machine (Lloyd Instruments Ltd, Segensworth, UK), which controls the 20-200 N/cm cyclic loading in an Hsine shape at 4 Hz for $6x10^6$ cycles (ISO/DIS 1480) (39). The cyclic load application was investigated in each sample by evaluating the presence or absence of abutment mobility with respect to the fixture. The samples were removed from the aluminum blocks and observed by X-ray microtomography consecutive acquisitions by Skyscan 1072 (SkyScan, Kartuizersweg 3B, 2550 Kontich, Belgium). To measure the implant-abutment interface, the presence of microgaps over and along the whole interface.

Statistical evaluation

The size of the micro-gap, expressed as a mean +/- standard deviation, was evaluated using the Analysis of Variance (ANOVA). Statistical significance was set at $p< 0.05$. Data treatment and statistical analysis were done using Excel, Origin, and SPSS software.

RESULTS

Implants before cyclic load

There was no detectable separation at the implant/abutment in the area of the conical connection, and it showed an absolute congruity with a 2-3 micron (mean 2.5 ± 0.1 μm) of microgaps between abutment and implant. No line was visible separating the implant and the abutment. The area of the conical connection had an extension of 3.5 ± 0.1 μm. In a few areas, gaps were present.

Implants after cyclic load

After applying a dynamic load, there was no evidence at a macroscopic level of mechanical failure referred to the interfaces between abutments and fixtures. In all samples, moreover, no abutment-fixture movement was recordable.

There was no detectable separation at the implant/abutment in the area of the conical connection, and it showed an absolute congruity with a 2-3 micron (mean 2.5 ± 0.1 μm) of the micro gap between abutment and implant (Fig. 1a, b).

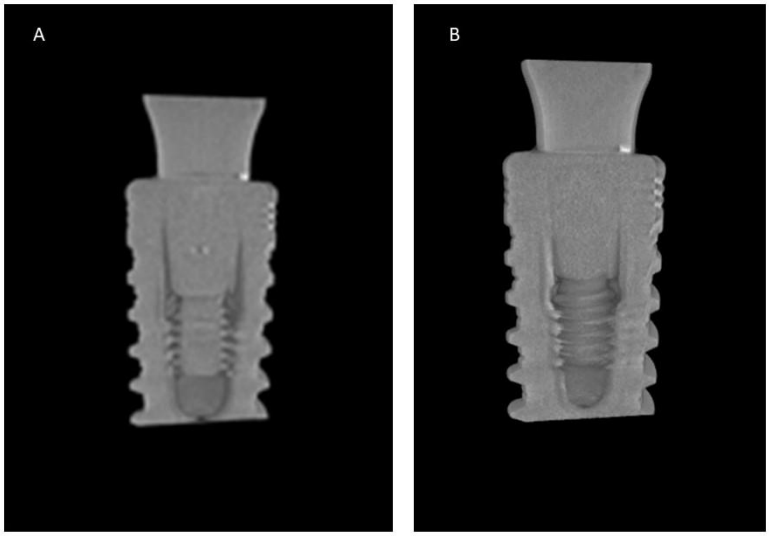


Fig. 1. *Micro-CT pictures of the marginal fit of interface implant-abutment after cyclic load. A microgap was detected before (A) and after cyclic load (B).*

Statistical evaluation

No statistically significant differences were found in the dimension of the microgap before and after cyclic loading (P= 0.17).

DISCUSSION

In this study, during the cone morse assemblies, a very small micro gap was found before and after undergoing $6x10^6$ loading cycles; this corresponds to approximately 6 years of in vivo function (38, 39). After applying the cyclic load to the cone morse abutment, the interface implant abutment showed an absolute congruity with 2.6 microns of micro gaps. There was no significant difference between the before and after a cyclic load. The quality of the surface machining of the conical abutment surfaces probably determined the resistance of the abutment interface. The structural geometric design of the implant connection has also been mentioned as a differential condition for maintaining stability at the implant/prosthesis interface. Cyclic loading of the implant-prosthesis assembly induces micromotion of the joint components, which could wear down the microscopically rough areas of the contacted surfaces, contributing to screw loosening by decreasing the preload. Many aspects guide the operator through choosing one implant system over another, and there are several connection designs between the implant and the abutment. An implant system with overlapping implant and abutment mating parts is known as a morse taper and represents an alternative to internal or external hexagon connection designs (40).

Conical interfaces (also called tapered interfaces), such as cone morse and locking cone systems, have shown a good fit between the implant and abutment (41, 42), which could, in principle, help avoid bacterial penetration. Many studies present results about bacterial penetration through the implant-abutment microgap, showing several degrees of colonization (43).

Conical morse taper connections have been shown to be more tight and stable from a biomechanical point of view than flat-to-flat connections (17). In all cone morse connection samples, no abutment-fixture movement was recordable.

In conclusion, the cone morse taper internal connection can resist cyclic load without creating spaces between the abutment and the implant.

REFERENCES

1. Cochran DL, Hermann JS, Schenk RK, Higginbottom FL, Buser D. Biologic Width Around Titanium Implants. A Histometric Analysis of the Implanto-Gingival Junction Around Unloaded and Loaded Nonsubmerged Implants in the Canine Mandible. *Journal of Periodontology*. 1997;68(2):186-197. doi:https://doi.org/10.1902/jop.1997.68.2.186
2. Hermann JS, Schoolfield JD, Schenk RK, Buser D, Cochran DL. Influence of the Size of the Microgap on Crestal Bone Changes Around Titanium Implants. A Histometric Evaluation of Unloaded Non-Submerged Implants in the Canine Mandible. *Journal of Periodontology*. 2001;72(10):1372-1383. doi:https://doi.org/10.1902/jop.2001.72.10.1372
3. Hoshaw SJ, Brunski JB, George. Mechanical Loading of Brånemark Implants Affects Interfacial Bone Modeling and Remodeling. KVM - Der Medizinverlag. Published May 1994. https://www.quintessence-publishing.com/kvm/de/article/843959/the-international-journal-of-oral-maxillofacial-implants/1994/03/mechanical-loading-of-brnemark-implants-affects-interfacial-bone-modeling-and-remodeling
4. Cho SC, Small PN, Elian N, Tarnow D. Screw Loosening for Standard and Wide Diameter Implants in Partially Edentulous Cases: 3- to 7-Year Longitudinal Data. *Implant Dentistry*. 2004;13(3):245-250. doi:https://doi.org/10.1097/01.id.0000140459.87333.f8
5. Kallus T, Bessing C. Loose gold screws frequently occur in full-arch fixed prostheses supported by osseointegrated implants after 5 years. *The International Journal of Oral & Maxillofacial Implants*. 1994;9(2):169-178.
6. Smedberg JI, K Nilner, Frykholm A. A six-year follow-up study of maxillary overdentures on osseointegrated implants. *Eur J Prosthodont Restor Dent* . 2000;7(2):51-56.
7. Quirynen M, Van Steenberghe D. Bacterial colonization of the internal part of two-stage implants. An in vivo study . *Clinical Oral Implants Research*. 1993;4(3):158-161. doi:https://doi.org/10.1034/j.1600-0501.1993.040307.x
8. Piattelli A, Scarano A, Paolantonio M, et al. Fluids and Microbial Penetration in the Internal Part of Cement-Retained Versus Screw-Retained Implant-Abutment Connections. *Journal of Periodontology*. 2001;72(9):1146-1150. doi:https://doi.org/10.1902/jop.2000.72.9.1146
9. Dibart S, Warbington M, Su MF, Skobe Z. In vitro evaluation of the implant-abutment bacterial seal: the locking taper system. *The International Journal of Oral & Maxillofacial Implants*. 2005;20(5):732-737.
10. Nascimento C do, Pita MS, Fernandes FHNC, Pedrazzi V, de Albuquerque Junior RF, Ribeiro RF. Bacterial adhesion on the titanium and zirconia abutment surfaces. *Clinical Oral Implants Research*. 2013;25(3):337-343. doi:https://doi.org/10.1111/clr.12093
11. COELHO PG, SUDACK P, SUZUKI M, KURTZ KS, ROMANOS GE, SILVA NRFA. In vitroevaluation of the implant abutment connection sealing capability of different implant systems. *Journal of Oral Rehabilitation*. 2008;35(12):917-924. doi:https://doi.org/10.1111/j.1365-2842.2008.01886.x
12. Do Nascimento C, Pedrazzi V, Miani PK, Moreira LD, De Albuquerque Junior RF. Influence of repeated screw tightening on bacterial leakage along the implant-abutment interface. *Clinical Oral Implants Research*. 2009;20(12):1394-1397. doi:https://doi.org/10.1111/j.1600-0501.2009.01769.x
13. Tesmer M, Wallet S, Koutouzis T, Lundgren T. Bacterial Colonization of the Dental Implant Fixture–Abutment Interface: An In Vitro Study. *Journal of Periodontology*. 2009;80(12):1991-1997. doi:https://doi.org/10.1902/jop.2009.090178
14. Assenza B, Tripodi D, Scarano A, et al. Bacterial Leakage in Implants With Different Implant–Abutment Connections: An In Vitro Study. *Journal of Periodontology*. 2012;83(4):491-497. doi:https://doi.org/10.1902/jop.2011.110320
15. D'Ercole S, Scarano A, Perrotti V, et al. Implants With Internal Hexagon and Conical Implant-Abutment Connections: An In Vitro Study of the Bacterial Contamination. *Journal of Oral Implantology*. 2014;40(1):30-34. doi:https://doi.org/10.1563/aaid-joi-d-11-00121
16. Tripodi D, Vantaggiato G, Scarano A, et al. An In Vitro Investigation Concerning the Bacterial Leakage at Implants With Internal Hexagon and Morse Taper Implant-Abutment Connections. *Implant Dentistry*. 2012;21(4):335-339. doi:https://doi.org/10.1097/id.0b013e31825cd472
17. Harder S, Dimaczek B, Açil Y, Terheyden H, Freitag-Wolf S, Kern M. Molecular leakage at implant-abutment connection—in vitro investigation of tightness of internal conical implant-abutment connections against endotoxin penetration. *Clinical Oral Investigations*. 2009;14(4):427-432. doi:https://doi.org/10.1007/s00784-009-0317-x
18. Aloise JP, Curcio R, Laporta MZ, Rossi L, da Silva AMÁ, Rapoport A. Microbial leakage through the implant-abutment interface of morse taper implantsin vitro. *Clinical Oral Implants Research*. 2010;21(3):328-335. doi:https://doi.org/10.1111/j.1600-0501.2009.01837.x
19. Steinebrunner L, Wolfart S, Bössmann K, Kern M. In vitro evaluation of bacterial leakage along the implant-abutment interface of different implant systems. *The International Journal of Oral & Maxillofacial Implants*. 2005;20(6):875-881.
20. Jansen VK, Conrads G, Richter EJ. Microbial leakage and marginal fit of the implant-abutment interface. *The International Journal of Oral & Maxillofacial Implants*. 1997;12(4):527-540.
21. Persson LG, Lekholm U, Leonhardt A, Dahlen G, Lindhe J. Bacterial colonization on internal surfaces of Branemark systemR implant components. *Clinical Oral Implants Research*. 1996;7(2):90-95. doi:https://doi.org/10.1034/j.1600-

0501.1996.070201.x

22. Broggini N, McManus LM, Hermann JS, et al. Peri-implant Inflammation Defined by the Implant-Abutment Interface. *Journal of Dental Research*. 2006;85(5):473-478. doi:https://doi.org/10.1177/154405910608500515
23. Orsini G, Fanali S, Scarano A, Petrone G, di Silvestro S, Piattelli A. Tissue reactions, fluids, and bacterial infiltration in implants retrieved at autopsy: a case report. *Int J Oral Maxillofac Implants*. 2000;15(2):283-286.
24. Ali Rifat Boynuegri, Mehmet Yalim, Seçil Karakoca Nemli, B. İmge Ergüder, Pelin Gökalp. Effect of different localizations of microgap on clinical parameters and inflammatory cytokines in peri-implant crevicular fluid: a prospective comparative study. *Clin Oral Invest*. 2011;16(2):353-361. doi:https://doi.org/10.1007/s00784-010-0497-4
25. M.-A. Fauroux, Levallois B, Yachouh J, Torres JH. Assessment of leakage at the implant-abutment connection using a new gas flow method. *HAL (Le Centre pour la Communication Scientifique Directe)*. 2012;27(6):1409-1412.
26. do Nascimento C, Miani PK, Pedrazzi V, et al. Leakage of saliva through the implant-abutment interface: in vitro evaluation of three different implant connections under unloaded and loaded conditions. *Int J Oral Maxillofac Implants*. 2012;27(3):551-560.
27. Mario Eduardo Jaworski, Cláudia A, Telles M, de A. Analysis of the bacterial seal at the implant-abutment interface in external-hexagon and Morse taper-connection implants: an in vitro study using a new methodology. *PubMed*. 2012;27(5):1091-1095.
28. Gross M, Abramovich I, Weiss EI. Microleakage at the abutment-implant interface of osseointegrated implants: a comparative study. *Int J Oral Maxillofac Implants*. 1999;14(1):94-100.
29. Oji C, Chukwuneke F. Evaluation and treatment of oral candidiasis in HIV/AIDS patients in Enugu, Nigeria. *Oral and Maxillofacial Surgery*. 2008;12(2):67-71. doi:https://doi.org/10.1007/s10006-008-0106-8
30. Cassio do Nascimento, Paola Kirsten Miani, Watanabe E, Vinicius Pedrazzi, Rubens. In vitro evaluation of bacterial leakage along the implant-abutment interface of an external-hex implant after saliva incubation. *Int J Oral Maxillofac Implants*. 2011;26(4):782-787.
31. da Silva-Neto JP, Nóbilo MA de A, Penatti MPA, Simamoto PC, das Neves FD. Influence of methodologic aspects on the results of implant-abutment interface microleakage tests: a critical review of in vitro studies. *The International Journal of Oral & Maxillofacial Implants*. 2012;27(4):793-800.
32. Assenza B, Scarano A, Petrone G, et al. Crestal Bone Remodeling in Loaded and Unloaded Implants and the Microgap: A Histologic Study. *Implant Dentistry*. 2003;12(3):235-241. doi:https://doi.org/10.1097/01.id.0000074081.17978.7e
33. Yokoyama K, Ichikawa T, Murakami H, Miyamoto Y, Asaoka K. Fracture mechanisms of retrieved titanium screw thread in dental implant. *Biomaterials*. 2002;23(12):2459-2465. doi:https://doi.org/10.1016/s0142-9612(01)00380-5
34. Assenza B, Scarano A, Leghissa G, et al. Screw- vs Cement-implant–retained Restorations: An Experimental Study in the Beagle. Part 1. Screw and Abutment Loosening. *Journal of Oral Implantology*. 2005;31(5):242-246. doi:https://doi.org/10.1563/1548-1336(2005)31%5B242:svcrae%5D2.0.co;2
35. Scarano A, Assenza B, Piattelli M, et al. A 16–year Study of the Microgap Between 272 Human Titanium Implants and Their Abutments. *Journal of Oral Implantology*. 2005;31(6):269-275. doi:https://doi.org/10.1563/753.1
36. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JYK. Clinical complications with implants and implant prostheses. *The Journal of Prosthetic Dentistry*. 2003;90(2):121-132. doi:https://doi.org/10.1016/s0022-3913(03)00212-9
37. Seetoh YL, Tan KB, Chua EK, Quek HC, Nicholls JI. Load fatigue performance of conical implant-abutment connections. *PubMed*. 2011;26(4):797-806.
38. Cibirka RM, Nelson SK, Lang BR, Rueggeberg FA. Examination of the implant—abutment interface after fatigue testing. *The Journal of Prosthetic Dentistry*. 2001;85(3):268-275. doi:https://doi.org/10.1067/mpr.2001.114266
39. Organization for International Standard. Dentistry — Implants — Dynamic loading test for endosseous dental implants. ISO. Published 2016. https://www.iso.org/standard/61997.html
40. Moris ICM, Faria ACL, de Mattos M da GC, Ribeiro RF, Rodrigues RCS. Mechanical analysis of conventional and small diameter conical implant abutments. *The Journal of Advanced Prosthodontics*. 2012;4(3):158. doi:https://doi.org/10.4047/jap.2012.4.3.158
41. Scarano A, Valbonetti L, Degidi M, et al. Implant-Abutment Contact Surfaces and Microgap Measurements of Different Implant Connections Under 3-Dimensional X-Ray Microtomography. *Implant Dentistry*. 2016;25(5):656-662. doi:https://doi.org/10.1097/id.0000000000000465
42. Bressan E, Grusovin MG, D'Avenia F, et al. The influence of repeated abutment changes on peri-implant tissue stability: 3-year post-loading results from a multicentre randomised controlled trial. *European Journal of Oral Implantology*. 2017;10(4):373-390.
43. Barone A, Alfonsi F, Derchi G, et al. The Effect of Insertion Torque on the Clinical Outcome of Single Implants: A Randomized Clinical Trial. *Clinical Implant Dentistry and Related Research*. 2015;18(3):588-600. doi:https://doi.org/10.1111/cid.12337

Evaluation Study

TITANIUM MODULATES DENTAL PULP STEM CELL DIFFERENTIATION

P. Daliu[1], E. Isufaj[1] and A. Pellati[2]

[1]Dental School, Albanian University, Tirana, Albany
[2]Dept of Translational Medicine, University of Ferrara, Ferrara, Italy

Correspondence to:
Agnese Pellati, PhD
Dept of Translational Medicine
Universiti of Ferrara,
44100 Ferrara, Italy
e-mail: agnese.pellati@unife.it

ABSTRACT

Titanium (Ti) is the most widely used material for dental, orthopedic, and maxillofacial applications because of its excellent biocompatibility and mechanical properties. Several studies have suggested that implant anchorage to bone and soft tissue can be modulated by surface characteristics. Therefore, we studied how titanium can induce osteoblast differentiation in stem cells derived from dental pulp by measuring the expression levels of bone-related genes and stem cell markers using real-time polymerase chain reaction. The results demonstrated that the upregulation of SP7 and MMP12 enhanced differentiation via the activation of stem cells. Titanium disks facilitate implant integration and promote cell activation.

KEYWORDS: *titanium, disks, osteoblasts, gene, expression*

INTRODUCTION

Titanium implants are renowned for their biocompatibility, which allows osseointegration, the direct structural and functional connection between the implant and the surrounding bone tissue. Additionally, titanium exhibits excellent corrosion resistance, ensuring long-term stability and durability of dental implants in the oral environment. Moreover, the mechanical properties of titanium, including its high strength make it an ideal material for dental implantation (1-3).

Titanium dental implants are used in various clinical scenarios, including single-tooth replacement, multiple-tooth restorations, and full-arch rehabilitation. They offer predictable outcomes and provide patients with functional and aesthetically pleasing solutions for missing teeth. Titanium implants are compatible with various prosthetic options ranging from single crowns to fixed bridges and implant-supported overdentures (4, 5).

Titanium dental implants offer several advantages, including high success rates, excellent long-term stability, and minimal invasiveness during placement. Their biocompatibility ensures a favorable tissue response, facilitates osseointegration, and promotes long-term implant survival. Titanium implants also provide clinicians with versatility in treatment planning, thereby enabling tailored solutions to meet individual patient needs (6, 7).

Titanium has revolutionized modern dentistry owing to its unique properties and versatile applications. This light, strong, and biocompatible metal is currently the material of choice for dental implants, prosthetics, and other dental devices. Its ability to bond with bone (osseointegration) and corrosion resistance make it an ideal material for long-term dental applications (2, 8).

Received: 14 September 2022
Accepted: 10 October 2022

Titanium, particularly in its commercially pure form (cpTi) and titanium alloys, exhibits several properties that make it highly suitable for dental applications. Titanium is non-toxic and not rejected by the body, which minimizes the risk of adverse reactions and ensures patient safety.

Titanium dental implants have a high success rate, often exceeding 95%, which makes them a reliable choice for tooth replacement. The ability of titanium to integrate with the bone and tissue reduces discomfort and provides a natural look and feel, enhancing patient satisfaction. Ti can be tailored for various dental needs, from small orthodontic wires to robust implant posts, catering to a wide range of treatments (9, 10).

Integrating Ti with stem cell technology has led to innovative solutions in several medical fields (11-13). For this reason, we studied how titanium can induce osteoblast differentiation in stem cells derived from dental pulp (DPSCs) by measuring the expression levels of bone-related genes and mesenchymal stem cell markers by real-time RT-PCR. In addition, we investigated the same gene in the well-known cell line TE85. TE85 cells, derived from a human osteosarcoma cell line, are widely used in bone biology, cancer biology, and cell signaling pathways research.

MATERIALS AND METHODS

Dental Pulp Stem Cells (DPSCs) Isolation

Dental pulp was extracted from the third molars of healthy subjects and digested for 1 h at 37°C in a solution containing 1 mg/ml collagenase type I and 1 mg/ml dispase, dissolved in phosphate-buffered saline (PBS) supplemented with 100 U/ml penicillin, 100 µg/ml streptomycin, and 500 µg/ml clarithromycin. The solution was then filtered using 70 µm Falcon strainers (Sigma Aldrich, St Louis, Mo, U.S.A.) to separate mesenchymal stem cells from fibroblasts. Stem cells were cultivated in α-MEM culture medium (Sigma Aldrich, St Louis, Mo, U.S.A.) supplemented with 20% Fetal Bovine Serum (FBS), 100 µM 2P-ascorbic acid, 2 mM L-glutamine, 100 U/ml penicillin, and 100 µg/ml streptomycin (Sigma Aldrich, St Louis, Mo, U.S.A.). The flasks were incubated at 37 °C and 5% CO_2, and the medium was changed twice per week.

DPSCs were characterized by immunofluorescence for the cytoskeletal component vimentin, positive mesenchymal stem cell markers CD90 and CD73, and the negative marker CD34 as described in Sollazzo et al. (14).

TE85 cell culture

TE85 osteosarcoma cell lines were cultured in sterile wells containing DMEM supplemented with 10% FBS and antibiotics (penicillin 100 U/ml and streptomycin 100 µg/ml). Cultures were maintained in a 5% CO_2 humidified atmosphere at 37°C.

Cell treatment

DPSCs and TE85 were seeded at a concentration of 1.0×10^5 cells/ml on titanium disks in 9 cm^2 (3 ml) wells containing DMEM supplemented with 10% serum and antibiotics. Another set of wells containing untreated cells was used as control. The treatment was carried out at two time points: 24 h and 4 days.

The cells were maintained in a humidified atmosphere containing 5% CO_2 at 37°C. At the end of the treatment period, the cells were lysed and processed for total RNA extraction.

RNA isolation, reverse transcription, and quantitative real-time RT-PCR

According to the manufacturer's instructions, total RNA was isolated from the cells using RNeasy Mini Kit (Qiagen, Hilden, Germany). The pure RNA was quantified using a NanoDrop 2000 spectrophotometer (Thermo Fisher Scientific, Wilmington, DE, USA).

cDNA synthesis was performed starting from 500 ng of total RNA using the PrimeScript RT Master Mix (Takara Bio Inc., Kusatsu, Japan). The reaction mixture was incubated at 37 °C for 15 min and inactivated by heating at 70 °C for 10 s. cDNA was amplified by real-time quantitative PCR using an ABI PRISM 7500 (Applied Biosystems, Foster City, CA, USA). All PCR reactions were performed in a 20 µL volume. Each reaction contained 10 µl of 2x qPCRBIO SYGreen Mix Lo-ROX (PCR Biosystems, Ltd., London, UK), 400 nM of each primer, and cDNA.

Sigma Aldrich purchased custom primers belonging to the “extracellular matrix, adhesion molecule” pathway, “osteoblast differentiation” pathway, and “inflammation” pathway. Table I lists the selected genes grouped by functional pathways.

Table I. *Selected genes used in Real Time PCR grouped by functional pathway.*

Pathway	Gene
Osteoblast differentiation	SPP1 (Osteopontin) SPARC (Osteonectin) RUNX2 (Runt-related transcription factor 2) ALP (Alkaline phospatasi) BGLAP (Osteocalcin) FOSL1 (FOS-like antigen 1) SP7 (Osterix) ENG (Endoglin)
Extracellular matrix, adhesion molecule	COL1A1 (Collagen type I alpha1) COL3A1 (Collagen, type III, alpha 1) MMP7 (Matrix Metallopeptidase 7) MMP12 (Matrix Metallopeptidase 12)
Inflammation	IL1α (Interleukin 1 Alpha) IL1R (Interleukin 1 Receptor Type 1)
Reference gene	RPL13 (Ribosomal protein L13)

All experiments were performed using non-template controls to exclude reagent contamination. PCR was performed using two analytical replicates. The amplification profile was initiated by incubation for 10 min at 95°C, followed by a two-step amplification for 15 s at 95°C and 60 s at 60°C for 40 cycles. In the final step, melt curve dissociation analysis was performed.

Statistical analysis

The gene expression levels were normalized to the expression of the reference gene (RPL13) and expressed as fold changes relative to the expression in untreated cells. Quantification was performed using the delta-delta Ct method (10).

RESULTS

The DPCSs were phenotypically characterized using immunofluorescence. Fig. 1a shows cytoskeletal filaments stained with vimentin. The cell surfaces were positive for mesenchymal stem cell markers CD90 (Fig. 1b) and CD73 (Fig. 1c), and negative for markers of hematopoietic origin CD34 (Fig. 1d).

Titanium treatment in DPSCs was analyzed using quantitative real-time PCR after 24 h and 4 days of treatment, and the expression levels of osteoblast-related genes, extracellular matrix, and inflammation pathways were measured. Tables II and III report the significant fold changes obtained after 24 h and 4 days, respectively, for each cell type (DPSCs and TE85).

Significantly upregulated genes showed ≥ 2-fold change in expression (P value ≤ 0.05), while significantly downregulated genes showed ≤ 0.5 -fold change in expression (P value ≤ 0.05). After 24 h of treatment, SP7, MMP7, MMP12, and IL1α were strongly upregulated in DPSCs (Table II). MMP7 and MMP 12 levels decreased after four days. SP7, MMP7, and MMP12 were overexpressed (Table III).

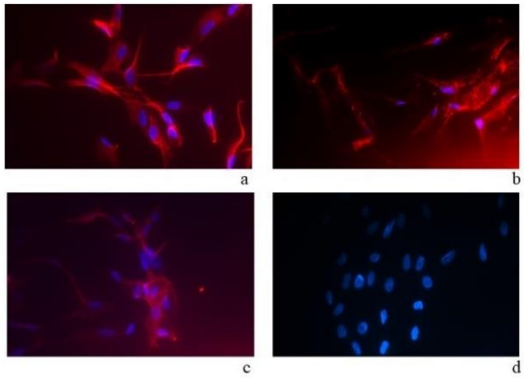


Fig. 1. *DPCSs by indirect immunofluorescence (Rhodamine). Immunofluorescence staining of vimentin (**a**), mesenchymal stem cell marker CD73 (**b**), CD90 (**c**), and hematopoietic markers CD34 (**d**). Nuclei were stained with DAPI. Original magnification x40.*

Table II. *Gene expression in DPSCs after 24h and 4 days of treatment. Numbers express the fold changes of the de-regulated genes in treated cells vs. untreated cells. ND – not determined. In bold significant gene expression level.*

Gene	24 h	4 days
SPP1	nd	nd
SPARC	0.8	0.6
RUNX2	0.7	0.7
ALP	0.7	0.3
BGLAP	nd	nd
FOSL1	nd	0.7
SP7	**8.3**	0.9
ENG	0.8	1.2
COL1A1	0.4	0.5
COL3A1	0.9	0.8
MMP7	**15.8**	**3.1**
MMP12	**6.8**	**2**
IL1α	**7.3**	1.2
IL1R	0.7	0.7

Table III. *Gene expression in TE85 after 24h and 4 days of treatment. Numbers express the fold changes of the de-regulated genes in treated cells vs. untreated cells. ND – not determined. In bold significant gene expression level.*

Gene	24 h	4 days
SPP1	0,59	0,86
SPARC	0,61	1,6
RUNX2	0,45	1,07
ALP	0,54	1,27
BGLAP	nd	nd
FOSL1	0,6	1
SP7	**9,5**	0
ENG	0,8	1,3
COL1A1	0,43	1,43
COL3A1	0,3	0,8
MMP7	**7,3**	0,5
MMP12	**7,1**	1,1
IL1α	1,4	1,8
IL1R	0,4	0,7

DISCUSSION

Since SP7 and MMP12 were upregulated after 24 h and 4 days, respectively, these genes seem to play a prominent role in the titanium-cell interaction.

SP7, also known as osterix, is a zinc-finger-containing transcription factor that plays a critical role in bone formation and osteoblast differentiation (15). Identified as a key regulator of the genetic network controlling osteogenesis, SP7 functions downstream of RUNX2, which is another essential transcription factor in bone development. The study of SP7 is vital for understanding the molecular mechanisms underlying bone formation, maintenance of bone health, and the pathogenesis of bone-related diseases (16).

SP7 is indispensable for osteoblast differentiation and bone formation. It acts primarily by binding to specific promoter regions of osteoblast-related genes, thereby activating their transcription. Key target genes include those encoding bone matrix proteins, such as collagen type I, osteocalcin, and bone sialoprotein, which are essential components of the extracellular matrix in the bone (15).

During skeletal development, SP7 expression was first detected in pre-osteoblasts and continues in mature osteoblasts, highlighting its role throughout the osteogenic lineage. The absence of SP7 results in a complete lack of bone formation, as observed in SP7 knockout mice, which exhibit severe skeletal defects and perinatal lethality. This underscores SP7's essential role in the transition of mesenchymal stem cells into fully differentiated osteoblasts.

In addition to its role in osteoblasts, SP7 influences the differentiation of chondrocytes, which are responsible for cartilage formation. Although primarily known for its osteogenic functions, emerging evidence suggests that SP7 may play a role in regulating the balance between osteogenesis and chondrogenesis, which is crucial for endochondral ossification, the process by which long bones are formed (17).

Given its pivotal role in bone formation, mutations in or dysregulation of SP7 have been associated with various bone disorders. Osteogenesis imperfecta, a genetic disorder characterized by brittle bone, has been linked to mutations in SP7. Patients with these mutations exhibit symptoms such as frequent fractures, bone deformities, and growth deficiencies, reflecting impaired osteoblast function and bone matrix production (18).

SP7 has also been implicated in osteoporosis, a condition characterized by reduced bone mass and an increased fracture risk. Dysregulation of SP7 expression or activity can disrupt the balance between bone formation and resorption, contributing to the development of osteoporosis (19). Inflammatory conditions such as rheumatoid arthritis also affect SP7 function, where chronic inflammation impairs osteoblast differentiation and activity, leading to bone erosion and joint damage.

Understanding SP7's role in bone biology opens new avenues for therapeutic interventions to enhance bone formation and treat bone-related diseases. SP7 is a target for developing biomaterials and scaffolds for bone tissue engineering in regenerative medicine. Incorporating SP7 or its modulators into scaffolds can enhance osteoblast differentiation and bone regeneration, thereby providing effective treatment for bone defects and fractures (20). Our study showed SP7 was up-regulated, demonstrating its important role in bone formation in implant dentistry.

Metalloproteinase 12 (MMP12), also known as macrophage elastase, is a member of the matrix metalloproteinase (MMP) family, which consists of enzymes responsible for the degradation of extracellular matrix (ECM) components. Macrophages primarily produce MMP12 which is notable for its ability to degrade elastin, a key ECM protein that provides tissue elasticity. This enzyme plays a significant role in tissue remodeling, inflammation, and various pathological conditions, including chronic obstructive pulmonary disease, atherosclerosis, and cancer.

The primary physiological role of MMP12 is the degradation and remodeling of the ECM, with a particular affinity for elastin. This elastolytic activity is crucial for maintaining tissue elasticity and integrity, particularly in tissues such as the lungs, skin, and blood vessels. MMP12 is involved in the turnover and repair of elastic fibers in the lungs, contributing to normal respiratory function (21).

MMP12 is also involved in the modulation of the inflammatory response. MMP12 facilitates the migration of immune cells to sites of injury or infection by degrading extracellular matrix components. MMP12 can process and activate other bioactive molecules, such as cytokines and chemokines, thereby influencing the inflammatory milieu (22).

The involvement of MMP12 in various diseases makes it a potential diagnostic and prognostic biomarker. Elevated MMP12 levels in tissues and bodily fluids can indicate disease activity and progression. Given its role in tissue destruction and inflammation, MMP12 is an attractive therapeutic target. MMP12 inhibitors have been explored for their potential in the treatment of diseases such as atherosclerosis and cancer. In our study, MMP12 expression was upregulated, demonstrating its important role in bone formation in implant dentistry.

CONCLUSIONS

SP7 and MMP12 are involved in the regulation of bone formation and osteoblast differentiation. Their essential roles in skeletal development and maintenance, combined with their involvement in various bone diseases, underscore their importance in bone biology.

REFERENCES

1. Albrektsson T, Berglundh T, Lindhe J. Osseointegration: Historic background and current concepts. *Clin. Periodontol. Implant Dent.* 2003;4(809–820.
2. Bosshardt DD, Chappuis V, Buser D. Osseointegration of titanium, titanium alloy and zirconia dental implants: current knowledge and open questions. *Periodontol 2000.* 2017;73(1):22-40. doi:https://doi.org/10.1111/prd.12179
3. Esposito M, Grusovin MG, Achille H, Coulthard P, Worthington HV. Interventions for replacing missing teeth: different times for loading dental implants. *Cochrane Database Syst Rev.* 2009;1):CD003878. doi:https://doi.org/10.1002/14651858.CD003878.pub4
4. Adell R, Lekholm U, Rockler B, Branemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg.* 1981;10(6):387-416. doi:https://doi.org/10.1016/s0300-9785(81)80077-4
5. Komiyama A, Klinge B, Hultin M. Treatment outcome of immediately loaded implants installed in edentulous jaws following computer-assisted virtual treatment planning and flapless surgery. *Clin Oral Implants Res.* 2008;19(7):677-685. doi:https://doi.org/10.1111/j.1600-0501.2008.01538.x
6. Zanolla J, Amado FM, da Silva WS, Ayub B, de Almeida AL, Soares S. Success rate in implant-supported overdenture and implant-supported fixed denture in cleft lip and palate patients. *Ann Maxillofac Surg.* 2016;6(2):223-227. doi:https://doi.org/10.4103/2231-0746.200338
7. Gallucci GO, Avrampou M, Taylor JC, Elpers J, Thalji G, Cooper LF. Maxillary Implant-Supported Fixed Prosthesis: A Survey of Reviews and Key Variables for Treatment Planning. *Int J Oral Maxillofac Implants.* 2016;31 Suppl(s192-197. doi:https://doi.org/10.11607/jomi.16suppl.g5.3
8. Ottria L, Lauritano D, Andreasi Bassi M, et al. Mechanical, chemical and biological aspects of titanium and titanium alloys in implant dentistry. *Journal of Biological Regulators and Homeostatic Agents.* 2018;32(2):81-90.
9. Rotundo R, Pagliaro U, Bendinelli E, Esposito M, Buti J. Long-term outcomes of soft tissue augmentation around dental implants on soft and hard tissue stability: a systematic review. *Clin Oral Implants Res.* 2015;26 Suppl 11(123-138. doi:https://doi.org/10.1111/clr.12629
10. Thoma DS, Naenni N, Figuero E, et al. Effects of soft tissue augmentation procedures on peri-implant health or disease: A systematic review and meta-analysis. *Clin Oral Implants Res.* 2018;29 Suppl 15(32-49. doi:https://doi.org/10.1111/clr.13114
11. Insua A, Monje A, Wang HL, Miron RJ. Basis of bone metabolism around dental implants during osseointegration and peri-implant bone loss. *J Biomed Mater Res A.* 2017;105(7):2075-2089. doi:https://doi.org/10.1002/jbm.a.36060

12. Pittenger MF, Mackay AM, Beck SC, et al. Multilineage potential of adult human mesenchymal stem cells. *Science.* 1999;284(5411):143-147. doi:https://doi.org/10.1126/science.284.5411.143
13. Gothberg C, Grondahl K, Omar O, Thomsen P, Slotte C. Bone and soft tissue outcomes, risk factors, and complications of implant-supported prostheses: 5-Years RCT with different abutment types and loading protocols. *Clin Implant Dent Relat Res.* 2018;20(3):313-321. doi:https://doi.org/10.1111/cid.12587
14. Sollazzo V, Lucchese A, Palmieri A, et al. Calcium sulfate stimulates pulp stem cells towards osteoblasts differentiation. *International Journal of Immunopathology and Pharmacology.* 2011;24(2 SUPPL. 1):51S-57S. doi:https://doi.org/10.1177/03946320110240s210
15. Zhu F, Friedman MS, Luo W, Woolf P, Hankenson KD. The transcription factor osterix (SP7) regulates BMP6-induced human osteoblast differentiation. *J Cell Physiol.* 2012;227(6):2677-2685. doi:https://doi.org/10.1002/jcp.23010
16. Coffman JA. Runx transcription factors and the developmental balance between cell proliferation and differentiation. *Cell Biol Int.* 2003;27(4):315-324. doi:https://doi.org/10.1016/s1065-6995(03)00018-0
17. Della Bella E, Menzel U, Basoli V, Tourbier C, Alini M, Stoddart MJ. Differential Regulation of circRNA, miRNA, and piRNA during Early Osteogenic and Chondrogenic Differentiation of Human Mesenchymal Stromal Cells. *Cells.* 2020;9(2):doi:https://doi.org/10.3390/cells9020398
18. Sam JE, Dharmalingam M. Osteogenesis Imperfecta. *Indian J Endocrinol Metab.* 2017;21(6):903-908. doi:https://doi.org/10.4103/ijem.IJEM_220_17
19. Chan WCW, Tan Z, To MKT, Chan D. Regulation and Role of Transcription Factors in Osteogenesis. *Int J Mol Sci.* 2021;22(11):doi:https://doi.org/10.3390/ijms22115445
20. Tatullo M, Codispoti B, Paduano F, Nuzzolese M, Makeeva I. Strategic Tools in Regenerative and Translational Dentistry. *Int J Mol Sci*. 2019;20(8):1879. Published 2019 Apr 16. doi:10.3390/ijms20081879
21. Elkington PT, Friedland JS. Matrix metalloproteinases in destructive pulmonary pathology. *Thorax.* 2006;61(3):259-266. doi:https://doi.org/10.1136/thx.2005.051979
22. Wang X, Khalil RA. Matrix Metalloproteinases, Vascular Remodeling, and Vascular Disease. *Adv Pharmacol.* 2018;81(241-330. doi:https://doi.org/10.1016/bs.apha.2017.08.002

Case Report

GUIDED BONE REGENERATION FOR TREATING POSTERIOR MANDIBULAR ATROPHY: A CASE REPORT OF EXCEEDING THIN CREST

L. Tomaselli

Private practice, Bologna, Italy

Correspondence to:
Luigi Tomaselli, DDS, MS
Private practice,
Via Azzurra 26,
40138 Bologna, Italy
e-mail: gigitomaselli@gmail.com

ABSTRACT

Oral rehabilitation of mandibular atrophy involves restoring function and aesthetics to patients who have experienced significant bone loss. This condition, often resulting from tooth loss, aging, or systemic diseases, presents challenges for dental practitioners. Effective rehabilitation requires a combination of surgical and prosthetics. In this case report, we offered a surgical solution with bone grafts, membrane use, and insertion of dental implants in one surgical step, improving patients' ability to chew, speak, and smile confidently.

KEYWORDS: *atrophic, mandible, posterior, ridge, augmentation, onlay, graft, implants*

INTRODUCTION

Oral rehabilitation of mandibular atrophy (ORMA) involves restoring function and aesthetics to patients who have experienced significant bone loss. This condition, often resulting from tooth loss, aging, or systemic diseases, presents challenges for dental practitioners. Effective rehabilitation requires a combination of surgical, prosthetic, and sometimes regenerative techniques to ensure successful outcomes (1-2).

Mandibular atrophy is the progressive resorption and loss of alveolar bone in the lower jaw. This condition can lead to several complications, such as reduced bone volume (a significant decrease in bone height and width, complicating the placement of dental implants) and changes in jaw shape and structure that can affect facial aesthetics and function. Finally, due to lack of support, mandibular atrophy can lead to functional impairment, such as difficulty in chewing, speaking, and maintaining oral prostheses (3).

The etiology of mandibular atrophy is mainly related to tooth loss. Other conditions could be systemic diseases and periodontitis. Tooth loss is the most common cause, where loss of mechanical stimulation from teeth accelerates bone resorption. Natural bone loss associated with aging processes can also provoke mandibular atrophy. Diseases such as osteoporosis can reduce bone density throughout the body, including the mandible. Chronic gum disease can lead to the destruction of supporting bone around teeth (4).

A comprehensive diagnostic assessment is essential for planning ORMA. Evaluating the patient's oral health, assessing soft tissue conditions, and identifying existing dental issues are crucial for planning oral rehabilitation. Panoramic radiographs and cone-beam computed tomography (CBCT) provide detailed views of bone structure, density, and the location of vital anatomical structures such as the mandibular nerve. Reviewing the patient's systemic health to identify any factors that might affect bone regeneration or surgical outcomes is mandatory.

Received: 23 September 2022
Accepted: 02 November 2022

ORMA typically involves a multidisciplinary approach combining surgical and prosthetic interventions. Bone augmentation can be assessed using bone grafting, guided bone regeneration (GBR), and distraction osteogenesis (5). Bone grafts can be harvested in different ways: autogenous bone grafts (from the patient's own body), allografts (from a donor), xenografts (from another species), or synthetic materials. GBR is a method used for bone augmentation. GBR uses barrier membranes to direct the growth of new bone and prevent the invasion of soft tissues into the graft site (6). Instead, distraction osteogenesis is a process where the bone is gradually lengthened by surgically cutting the bone and then slowly separating the two segments, allowing new bone to form in the gap (7).

Dental implants are a cornerstone of ORMA, providing stable support for prosthetic teeth. Titanium or zirconia implants are surgically placed into the augmented bone. Accurate preoperative planning and imaging are crucial to avoid complications, especially with the mandibular nerve. Once osseointegration is achieved, various prosthetic options can be used, including single crowns, bridges, and full-arch prostheses (8). Prosthetic rehabilitation involves designing and fitting dental prostheses to restore function and aesthetics. Partial or complete dentures are often used when bone augmentation is not feasible or as an interim solution before implant placement. Implant-supported crowns and bridges permanently fixed in the mouth provide a more stable and natural-feeling solution than removable prostheses.

ORMA requires a patient-centered approach. ORMA must be tailored to the specific needs, anatomy, and health conditions of each patient, and the procedures, benefits, risks, and maintenance requirements of the prosthetic solutions must be understood. Regular monitoring and maintenance are needed to ensure the longevity and functionality of implants and prostheses. A case of exceeding atrophy of the posterior mandible is described here, treated in one surgical step using fixtures, heterologous mixed with autologous bone and covered with a non-resorbable-reinforced membrane.

CASE REPORT

A 58-year-old female presented to the dental office with complaints, including chewing difficulty and aesthetic dissatisfaction, owing to the absence of dental elements. The anamnesis revealed a frustrated rehabilitation attempt approximately 10 years previously with a partial prosthesis. As time went by, bone resorption occurred. The patient underwent a CBCT scan and orthopantomography. Clinical and radiographic examinations revealed severe mandibular atrophy (Fig. 1).

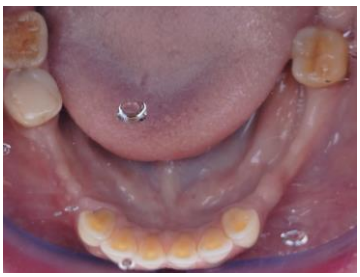


Fig. 1. *Endo-oral photos showing posterior partial edentulous mandible and an exceeding thin ridge.*

Rehabilitative surgical treatment was planned and assessed using 50% heterologous/autologous bone, reinforced membrane, and insertion of the implants in both the edentulous areas to achieve bone height and avoid mandibular fracture (Fig. 2-5).

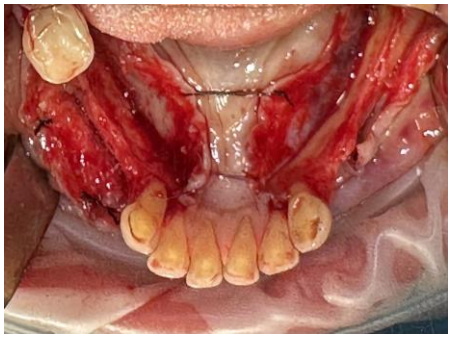


Fig. 2. *Mandibular posterior crest after detachment of mucosa and periosteum. The residual mandibular ridge appears very thin.*

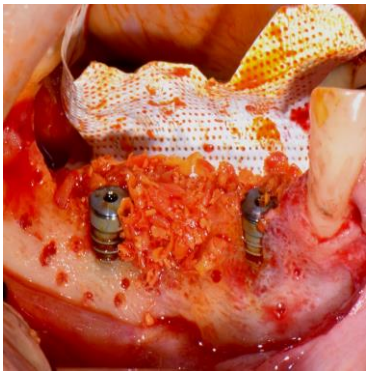


Fig. 3. *Insertion of dental implants covered with 50% heterologous/autologous bone and reinforced membrane.*

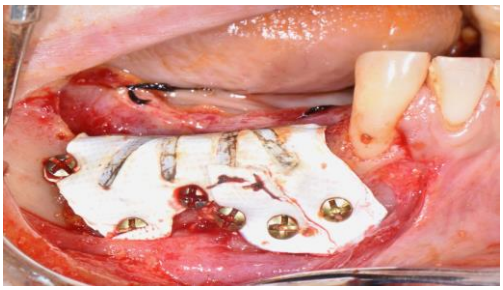


Fig. 4. *Lateral view of reinforced membrane stabilized with mini screws both in the lingual and vestibular side.*

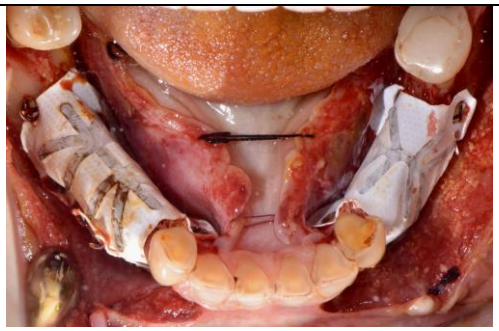


Fig. 5. *Occlusal view of two reinforced membranes stabilized with mini screws.*

Finally, the soft tissues were removed by horizontal cutting in the periosteum to reach an elongation and a passive repositioning of flaps and then sutured (Fig. 6).

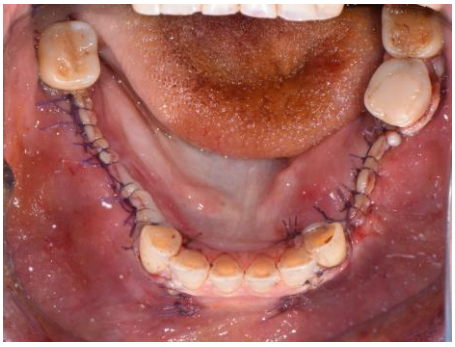


Fig. 6. *The mucous membrane is tight sutured at the end of surgery.*

The postoperative medication protocol consisted of antibiotics (amoxicillin 500 mg every 8 hours for 7 days), corticosteroids (dexamethasone 4mg every 12 hours for 3 days), anti-inflammatory and analgesic drug (ibuprofen 600 mg every 12 hours for 5 days), for treatment of pain or swelling. During the postoperative period, the patient reported mild-to-moderate pain for the first few days, with no progression of the condition. After 10 postoperative days, the sutures were removed (Fig. 7). Six months after surgery, the oral mucosa appeared healed (Fig. 8).

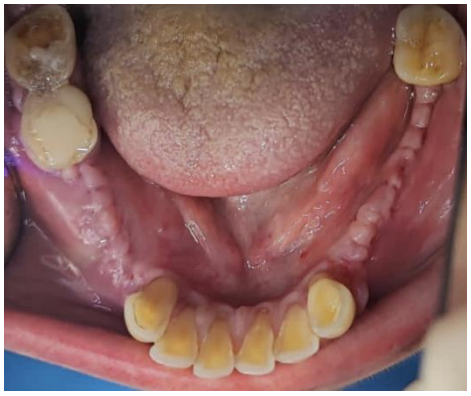


Fig. 7. *Removal of stitches 10 days after surgery. The mucosa appears perfectly healed.*

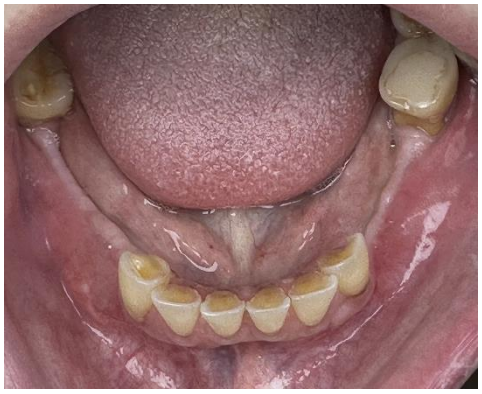


Fig. 8. *Clinical appearance of the mandibular mucosa 6 months after surgery. Note the reduced quantity of keratinized gingival on the top of aveolar ridge.*

Once the mucosa was healed, a fornix lengthening was performed by doing a sovra-periosteal flap and stretching the mobile gingiva in the lower part of the vestibule. Then, keratinized mucosa was collected from the palate and grafted bilaterally on the regenerated alveolar crest (Fig. 9-11).

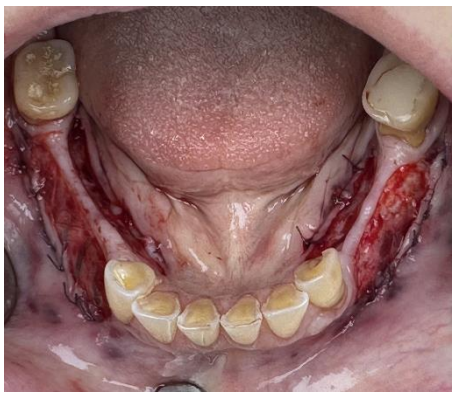


Fig. 9. *Deepening of the vestibular and lingual fornix by doing a sovra-periosteam flap sutured on lower part of vestibular and lingual ridge.*

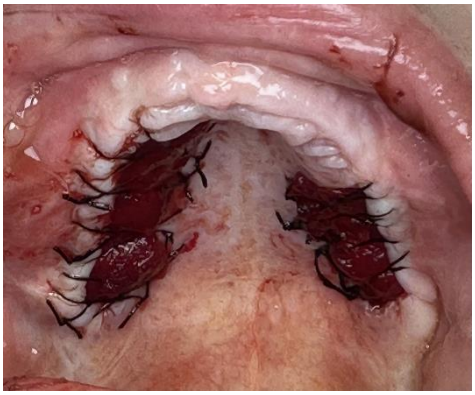


Fig. 10. *Palatal dome where keratinized mucosa was collected.*

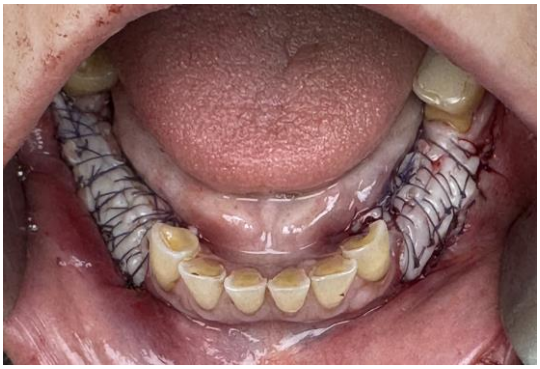


Fig. 11. *Keratinized mucosa bilaterally sutured on alveolar ridge.*

Two months later, the implants showed a good amount of alveolar bone (Fig. 12). The good quality of mucosa obtained by the augmentation done two months before was sutured around healing pillars. The sequence of soft tissue augmentation is visible in Fig. 13.

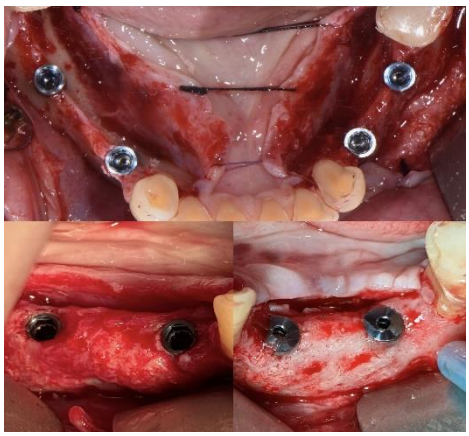


Fig. 12. *Comparison of bone dimension between pre- and 6 months post-regenerative procedure of posterior alveolar ridge.*

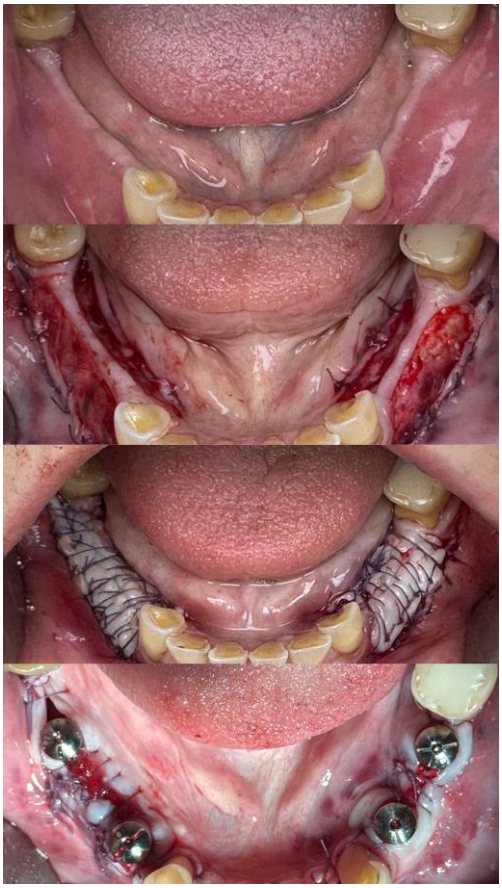


Fig. 13. *Comparison of soft tissue dimension between pre- and 2 months post-grafting procedure of posterior alveolar ridge (soft tissue).*

Then implants were prosthetically rehabilitated after one month of soft tissue healing around screws (Fig. 14). The follow up was uneventfully 3 years post-finalization of the case (Fig. 15, 16).

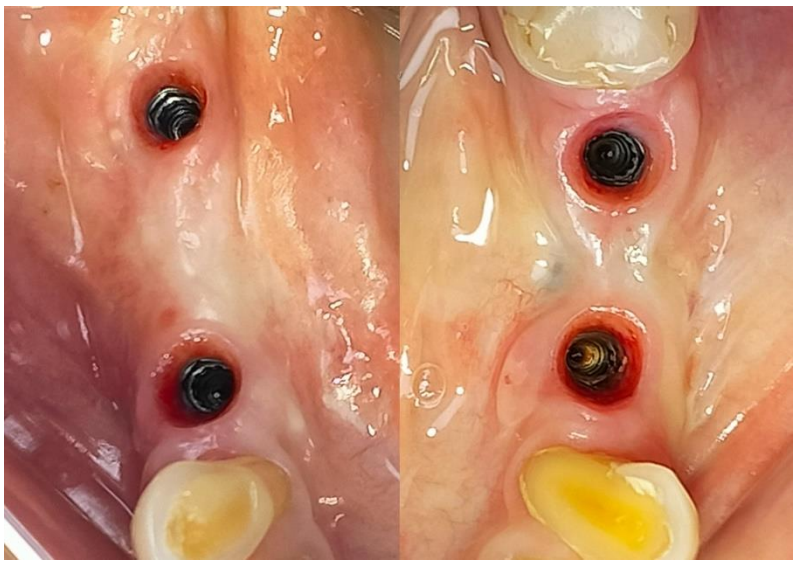


Fig. 14. *Peri-implant soft tissue healing at the time of digital impression.*

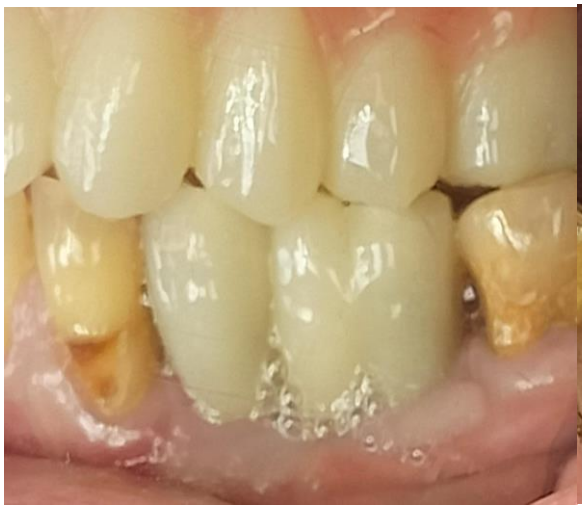


Fig. 15. Crown *#34-35-36.*

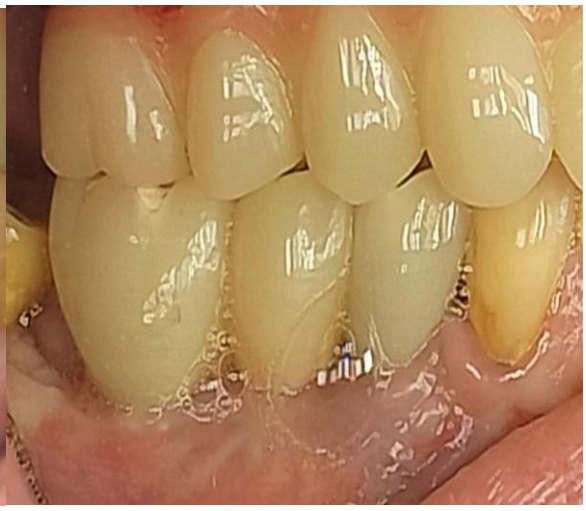


Fig. 16. *Crown #44-45-46.*

DISCUSSION

ORMA presents a significant challenge in modern dentistry. When severe atrophy makes the jaw unsuitable for dental implant placement, ORMA is necessary for replacing missing teeth.

Causes of mandibular atrophy could be tooth loss, trauma, denture wear, and periodontal disease. When teeth are extracted, the alveolar bone no longer receives the stimulation necessary to maintain its dimension, leading to gradual resorption of the bone over time. Fractures or injuries to the jaw can disrupt bone growth and healing, leading to localized atrophy. Ill-fitting dentures can put excessive pressure on the jawbone, accelerating resorption. Severe gum disease can damage the alveolar bone, contributing to atrophy. Certain medical conditions and medications can also contribute to bone loss in the jaw.

Consequences of mandibular atrophy are difficulty chewing, facial collapse, speech impediments, and social and psychological impact. Reduced jawbone volume can weaken the bite force, making it difficult to chew certain foods. Atrophy can alter facial contours, leading to a sunken appearance. Changes in jaw structure can affect speech patterns. The consequences can significantly impact a patient's quality of life and self-esteem.

Bone grafting offers a viable solution for restoring bone volume and enabling dental implant placement. The procedure involves transplanting bone tissue to the atrophied site, stimulating new bone growth, and creating a strong foundation for implants (9). However, bone block grafts require a second surgical field to be collected, which augments the operation time and surgical risks. Consequently, today GBR is the most used surgical technique.

From a general point of view, there are three main types of bone graft materials used: autogenous bone graft (from the patient’s own body), allograft (from a donor), and xenograft (from another species). Autogenous bone graft involves harvesting bone from another location in the patient's body, typically the chin, hip, or iliac crest. It offers the advantage of optimal biocompatibility and vascularization. Allograft bone utilizes bone tissue donated from a cadaver. Allografts are readily available and require minimal donor site morbidity but carry a small risk of disease transmission. Xenograft uses bone tissue derived from animals, most commonly cows. Xenografts are readily available and require no additional surgery for harvest (10). Here a 50% mixture of heterologous/autologous bone was used with optimal bone regeneration.

The choice of bone graft material and surgical technique depends on the severity of atrophy, the desired implant placement, and the patient's overall health. Mandibular bone grafting procedures are typically performed under local anesthesia on an outpatient basis. Healing time varies depending on the extent of the surgery but generally takes from 6 to 9 months. The reported case is an example that adds additional strength to this surgical technique. A rigid protocol is mandatory to reach successful results.

CONCLUSIONS

ORMA presents a significant challenge in implant dentistry. However, GBR offers a reliable and effective solution for restoring jawbone volume and enabling implant placement. By utilizing the appropriate graft material and

surgical approach, dentists can create a strong foundation for successful dental implants, improving patients' ability to chew, speak, and smile confidently.

ORMA is a complex but highly rewarding process that can significantly improve the quality of life for affected patients. Advances in surgical techniques, bone regeneration methods, and dental implant technology have greatly enhanced the success rates of these treatments. A multidisciplinary approach, meticulous planning, and patient-centered care are essential for optimal functional and aesthetic outcomes.

REFERENCES

1. Chiapasco M, Zaniboni M, Boisco M. Augmentation procedures for the rehabilitation of deficient edentulous ridges with oral implants. *Clin Oral Implants Res.* 2006;17(Suppl 2):136–59.
2. Clementini M, Morlupi A, Agrestini C, Ottria L. Success rate of dental implants inserted in autologous bone graft regenerated areas: a systematic review. *Oral Implantol (Rome).* 2011;4(3–4):3–10.
3. Dahlin C, Johansson A. Iliac crest ABG versus alloplastic graft and guided bone regeneration in the reconstruction of atrophic maxillae: a 5-year retrospective study on cost-effectiveness and clinical outcome. *Clin Implant Dent Relat Res.* 2011;13:305–10.
4. Misch CE, Perel ML, Wang HL, Sammartino G, Galindo-Moreno P, Trisi P. Implant success, survival, and failure: the International Congress of Oral Implantologists (ICOI) Pisa Consensus Conference. *Implant Dent.* 2008;17(1):5–15.
5. Carinci F, Farina A, Zanetti U, Vinci R, Negrini S, Calura G, Laino G, Piattelli A. Alveolar ridge augmentation: a comparative longitudinal study between calvaria and iliac crest bone grafrs. *J Oral Implantol.* 2005;31(1):39–45.
6. Liu J, Kerns DG. Mechanisms of guided bone regeneration: a review. *Open Dent J.* 2014; 8:56–65.
7. Sakkas A, Wilde F, Heufelder M, Winter K, Schramm A. Autogenous bone grafts in oral implantology—is it still a "gold standard"? A consecutive review of 279 patients with 456 clinical procedures. *Int J Implant Dent.* 2017; 3:23.
8. Garg AK. Bone biology, harvesting, & grafting for dental implants: rationale and clinical applications. *IL: Quintessence Publishing*; 2004.
9. Vermeeren JI, Wismeijer D, van Waas MA. One-step reconstruction of the severely resorbed mandible with onlay bone grafts and endosteal implants. A 5-year follow-up. *Int J Oral Maxillofac Surg.* 1996;25(2):112–5.
10. Kang YH, Kim HM, Byun JH, Kim UK, Sung IY, Cho YC, Park BW. Stability of simultaneously placed dental implants with autologous bone grafts harvested from the iliac crest or intraoral jawbone. *BMC Oral Health.* 2015; 15:172.

Case Report

TREATMENT OF NECK SOLITARY FIBROUS TUMOR: A CASE REPORT

R. De Luca[1], F. Funaioli[1,2], B. Pulli[1,2] and G. Spinelli[1]

[1]Department of Maxillo Facial Surgery, Azienda Ospedaliero-Universitaria Careggi, Florence, Italy
[2]Maxillo Facial Surgery University of Siena

[*]*Correspondence to:*
Roberto De Luca, DDS
Department of Maxillo Facial Surgery,
Azienda Ospedaliero-Universitaria Careggi,
Largo Giovanni Alessandro Brambilla, 3,
50134 Firenze FI, Italy
e-mail: robertodeluca89@yahoo.it

ABSTRACT

Solitary fibrous tumor is a rare tumor of mesenchymal origin that accounts for less than 2% of all soft tissue masses. Head and neck sites include the oral cavity, sinonasal region, soft tissues of the neck, thyroid, parotid gland, scalp, and larynx. Because of its rarity, developing specific diagnostic strategies and treatment planning was difficult. We report a case of a soft tissue solitary fibrous tumor of the neck in a 50-year-old male patient, localized between the small rectus muscle and the inferior oblique muscle of the head. We describe the diagnosis, pathological pattern, surgical treatment, and follow-up at 3 and 5 weeks after radical surgery.

KEYWORDS: *solitary fibrous tumor, sarcoma, neck, soft tissue neoplasms*

INTRODUCTION

Solitary fibrous tumor is a rare tumor of mesenchymal origin that accounts for less than 2% of all soft tissue masses (1). Initially identified in the pleura, solitary fibrous tumors has been identified in multiple anatomic locations and can arise anywhere in the body, like extremities, abdomen, superficial trunk, head, and neck (2-4).
Head and neck sites reported in the literature include the oral cavity, sinonasal region, soft tissues of the neck, thyroid, parotid gland, scalp, and larynx (4).

Because of the low incidence of solitary fibrous tumors, several data have been derived from small retrospective series and cases, making it difficult to develop specific diagnostic strategies and treatment planning. An extensive list of differential diagnoses and molecular genetic analyses must be considered to make a correct diagnosis. Solitary fibrous tumors have recently been associated with a NAB2-STAT6 gene fusion with high specificity and sensitivity (5).

Open incisional biopsy by an experienced surgeon or a central needle biopsy is mandatory. Depending on location, radiologically guided biopsy can be useful (6). Tumor size at presentation is highly variable and is typically related to location. The median size is between 7-10 cm, ranging from 1 to 40 cm (7-10). We report a case of a soft tissue solitary fibrous tumor of the neck, deeply localized between the small rectus muscle and the inferior oblique muscle of the head.

MATERIALS AND METHODS

Received: 15 October 2022
Accepted: 22 November 2022

A 50-year-old man presented a painless mass on the right side of his neck. Computed tomography (TC) scan revealed a well-defined, ovoid mass measuring 5.63 x 5,06 cm (Fig. 1a, b). The occipital artery and the occipital nerve were separated from the mass. Magnetic resonance imaging (MRI) revealed a mass related to the anterior border of the right inferior oblique muscle of the head. It was T2 hyperintense and T1 isointense to the muscle, with no post-contrast enhancement. Many blood vessels were seen within the mass. Based on these imaging findings, a borderline vascular lesion arising from the right inferior oblique muscle of the head was suggested. Instead, fine-needle aspiration cytology-biopsy revealed a solitary fibrous tumor.

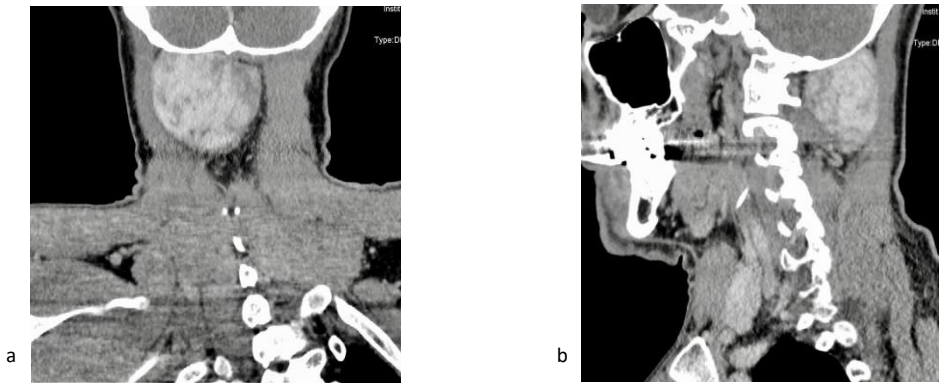
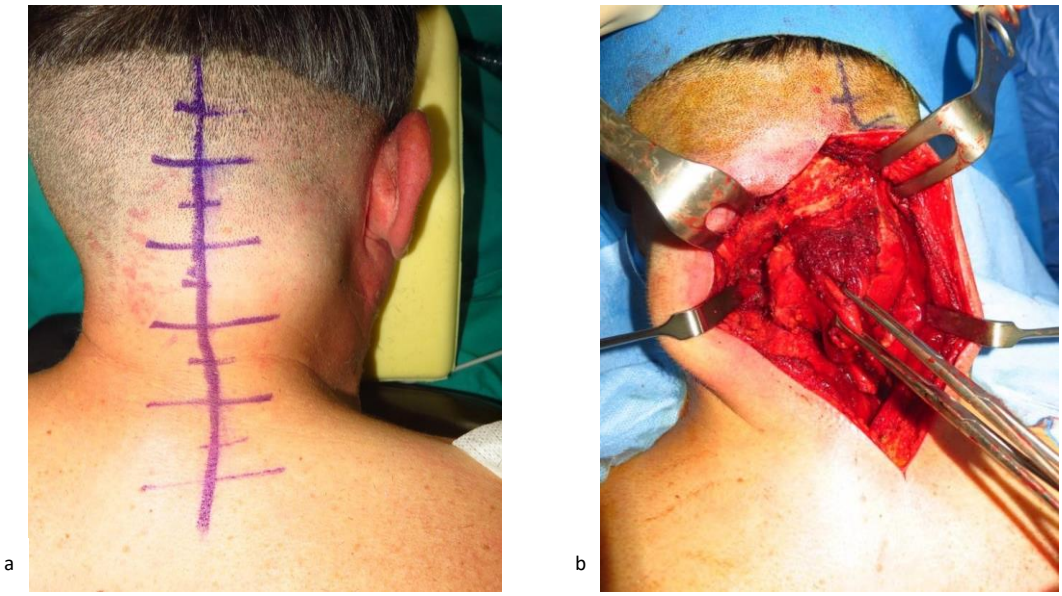
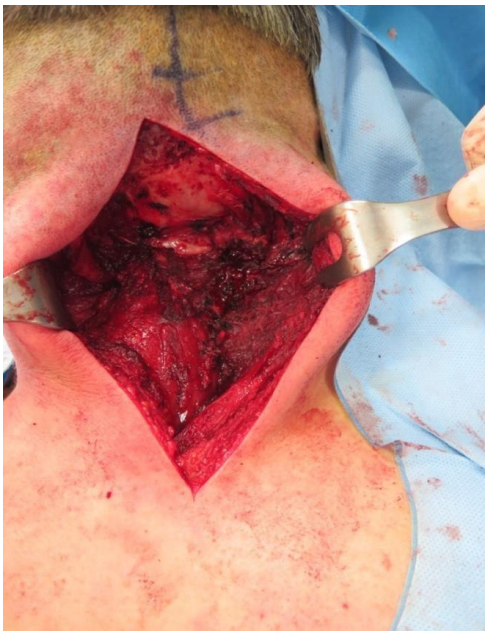


Fig. 1. *Computed tomography (TC) scan revealed a well-defined, ovoid mass; **a**): frontal view **b**): lateral view.*

Surgery was performed at Careggi Hospital by a multidisciplinary team consisting of maxillofacial surgeons, orthopedists, and neurosurgeons. The first surgical step was the incision of the skin and subcutaneous tissues (Fig. 2a), the incision of the trapezius muscle, the *Splenius capitis* muscle of the neck, the semifinal muscle of the head, and the small rectus muscle of the head. Subsequently, a blunt dissection was performed to find the mass that resulted adherent to the inferior oblique muscle of the head and the posterior big rectus muscle (Fig. 2b). The Occipital nerve and occipital artery were preserved. Dissection continued to the posterior arch of the atlas for complete mass removal (Fig. 2c). It was sent to a pathologist as a definitive exam (Fig. 2d).



c



d

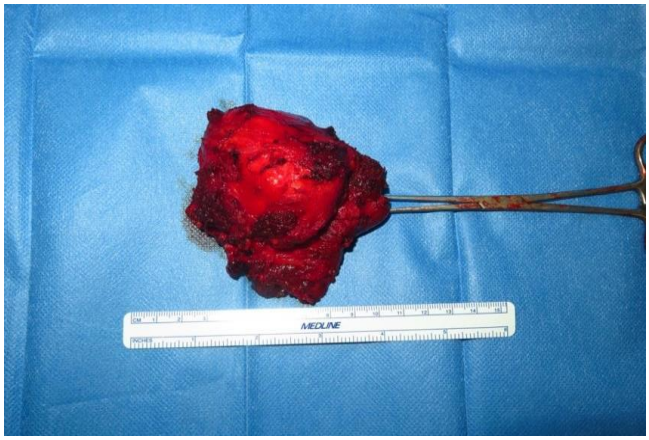
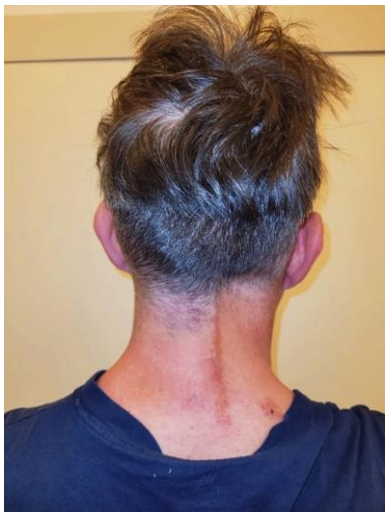


Fig. 2. ***a****): skin incision landmarks;* ***b****): blunt dissection of the mass;* ***c****): neck region after mass removal;* ***d****): excised mass.*

The patient was re-evaluated 3 weeks after surgery at our maxillofacial surgery department (Fig. 3a, b).The condition of the surgical wound was good. The patient reported paresthesia in the cervical and scalp region. Physiokinesis therapy was recommended.

a



b

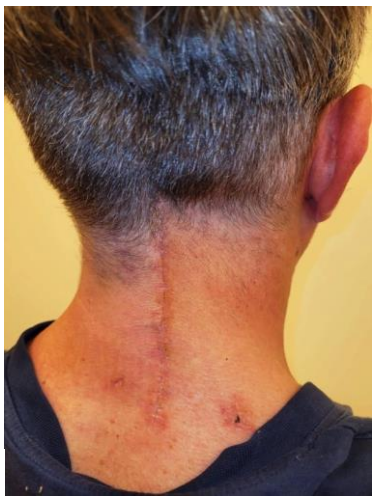


Fig. 3. *Check-up of surgical wound after 3 weeks.* ***a****): Posterior view;* ***b****): Lateral view.*

We also reported a subsequent follow-up 5 weeks after surgery: the patient showed a good surgical wound condition, but dysesthesia remained in the cervical and scalp region. The patient also reported a limitation in head torsion to the right, while the remaining movements of flexion-extension and rotation were preserved (Fig. 4a).

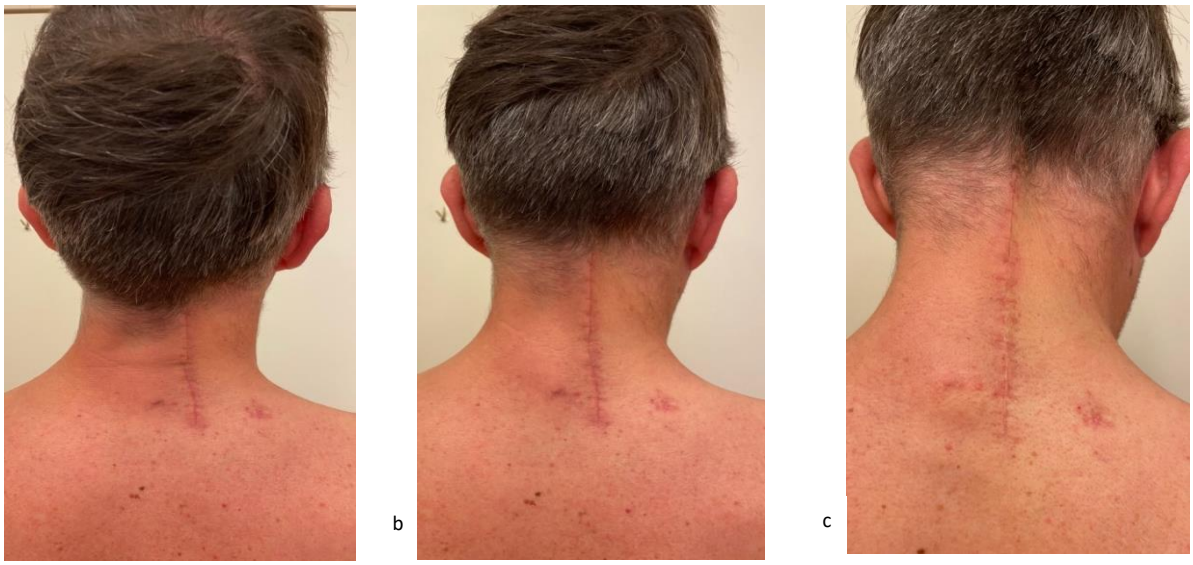


Fig. 4. *Check-up of neck movement at 5 weeks.* ***a****): Extension;* ***b****): Normal position* ***c****): Flexion.*

RESULTS

Gross specimen

The well-circumscribed ovoid mass measured 7 x 6 x 5 cm and was surrounded by fibro-adipose and skeletal muscle tissue. The lesion appeared solid and whitish on macroscopic examination and measured 4.4 x 3.8 cm (Fig. 2d). No necrosis or soft tissue invasion was identified.

Histopathology

Microscopic examination (Fig. 5a, Fig. 5b) revealed a well-circumscribed tumor composed of spindled to ovoidal cells with pale eosinophilic scant cytoplasm and indistinct cell borders surrounded by abundant myxoid stroma admixed with branching and hyalinized staghorn-shaped (haemangiopericytomatous) bloodvessel. No necrotic areas were found, and mitotic figures were rare (= 1/HPF). In view of these parameters,the age of the patient (<55 years), and the size of the lesion (<5 cm), the neoplasm has a low risk of recurrence and distant metastases (WHO 5th ed.).

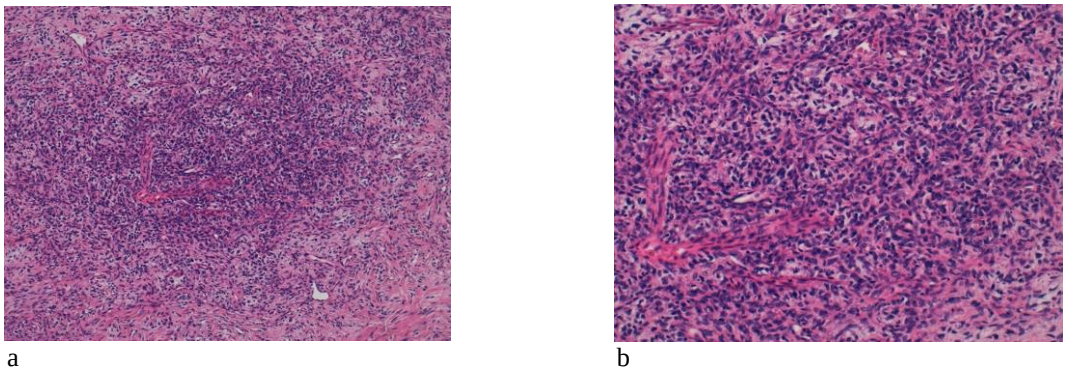
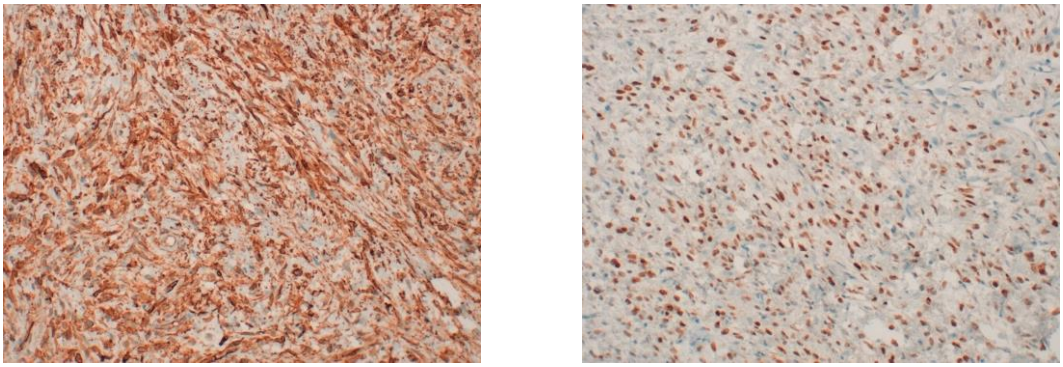


Fig. 5. ***a****): hematoxylin and Eosin stain, x100 magnification;* ***b****): hematoxylin and Eosin stain, x200 magnification.*

Immunohistochemistry

Immunohistochemical (IHC) investigations showed strong and widespread cytoplasmic positivity for CD34and a nuclear positivity for STAT6 in agreement with the diagnosis of SFT (Fig. 6a, b). The growth fraction of neoplastic cells evaluated with Ki67 equals 2%.



a b

Fig. 6. ***a****): the tumor cells diffusely expressed CD34 protein. Immunohistochemistry, CD34 antibody, x200 magnification;* ***b****): the tumor cells diffusely expressed STAT6 protein. Immunohistochemistry, STAT6 antibody, x200 magnification.*

DISCUSSION

Solitary fibrous tumors are fibroblastic tumors characterized by a prominent, branching, thin-walled, dilated (staghorn) vasculature and NAB2-STS6 gene rearrangement (12). Head and neck regions remain uncommon (18-22), accounting for only 11% in a series of 110 SFT cases by Demicco et al. (2).

Stanisce et al. estimated that a quarter of all extra-thoracic SFTs are localized in this region (4). Solitary fibrous tumors arising in the head and neck region are uncommon but well-recognized entities.

Davanzo et al. reported that SFT of the head and neck may originate from the sinonasal tract, oral cavity ororbit (1). In a recent meta-analysis, the median age at presentation of SFT was 51 years, and the median tumor size inthe neck was 5 cm (4). Recurrence (distal or local) occurs in 10-30% of SFTs, with 10-40% of recurrences reported after 5 years (12).

According to new recent WHO Classification of Tumor 5th Edition “Soft Tissue and Bone Tumors”, the most widely used model for metastatic risk incorporates mitotic count (≥ 2 mitoses/mm^2 or ≥ 4 mitoses/10 HPF) patient age (≥ 55 years) and tumor size stratified by 5 cm tiers to classify tumors into a low, intermediate,and high-risk group. A subsequent refinement includes necrosis as a fourth variable (12). Stanisce et al. found positive surgical resection margins to be the only significant risk factor for local recurrence (4).

Lau et al. presented a myxoid SFT occurring in the soft tissue of the neck and was treated with surgical resection alone and had no evidence of disease after 84 months of follow-up (13).

Our case was treated with surgical resection with negative margins at anatomy-pathological examination. No necrosis or soft tissue invasion was identified. The mitotic rate was 1per 10 high-power fields. Our multidisciplinary oncology group avoided postoperative adjuvant radiotherapy because the lesion was classified as a low-risk mass according to WHO guidelines (15). A nuclear magnetic resonance imaging scan was recommended 3 months after the last follow-up describedhere (5 weeks after radical surgery).

CONCLUSIONS

Literature suggests SFTs are associated with a favorable prognosis (11, 12). In conclusion, we described the diagnosis, treatment, and follow-up at 3 and 5 weeks after radical surgery of a solitary fibrous tumor arising from the soft tissue of the neck in a 50-year-old male patient.

REFERENCES

1. Davanzo B, Emerson RE, Lisy M, Koniaris LG, Kays JK. Solitary fibrous tumor. *Transl GastroenterolHepatol.* 2018 21;3:94. doi: 10.21037/tgh.2018.11.02.
2. Demicco, E., Park, M., Araujo, D. *et al.* Solitary fibrous tumor: a clinicopathological study of 110cases and proposed risk assessment model. *Mod Pathol* 25, 1298–1306 (2012). https://doi.org/10.1038/modpathol.2012.83
3. Bowe SN, Wakely PE Jr, Ozer E. Head and neck solitary fibroustumors: diagnostic and therapeutic challenges. *Laryngoscope.* 2012;122(8):1748–55. https ://doi.org/10.1002/lary.23350.
4. Stanisce L, Ahmad N, Levin K, Deckard N, Enriquez M, Brody J, Koshkareva Y. Solitary Fibrous Tumors in the Head and Neck: Comprehensive Review and Analysis. *Head Neck Pathol.* 2020;14(2):516-524. doi: 10.1007/s12105-019-01058-6.
5. Gold JS, Antonescu CR, Hajdu C, Ferrone CR, Hussain M, Lewis JJ, Brennan MF, Coit DG. Clinicopathologic correlates of solitary fibrous tumors. *Cancer.* 2002 15;94(4):1057-68.
6. Demicco EG, Park MS, Araujo DM, Fox PS, Bassett RL, Pollock RE, Lazar AJ, Wang WL. Solitaryfibrous tumor: a clinicopathological study of 110 cases and proposed risk assessment model. *Mod Pathol.* 2012 Sep;25(9):1298-306. doi: 10.1038/modpathol.2012.83.
7. Witkin GB, Rosai J. Solitary fibrous tumor of the mediastinum. A report of 14 cases. *Am J SurgPathol.* 1989 Jul;13(7):547-57. doi: 10.1097/00000478-198907000-00002.
8. Brunnemann RB, Ro JY, Ordonez NG, Mooney J, El-Naggar AK, Ayala AG. Extrapleural solitary fibrous tumor: a clinicopathologic study of 24 cases. *Mod Pathol.* 1999 Nov;12(11):1034-42.
9. Wu B, Tay SY, Petersson F. Cervical Myxoid Solitary Fibrous Tumor: Report of an Unusual Variantand a Brief Overview of the Literature. *Head Neck Pathol.* 2020 Sep;14(3):852-858. doi: 10.1007/s12105-019-01107-0.
10. von Mehren M, Randall RL, Benjamin RS, et al. Soft Tissue Sarcoma, Version 2.2018, NCCN Clinical Practice Guidelines in Oncology. *J Natl Compr Canc Netw.* 2018;16(5):536-563. doi: 10.6004/jnccn.2018.0025.
11. Lau SK, Weiss LM, Chu PG. Myxoid solitary fibrous tumor: a clinicopathologic study of three cases. *Virchows Arch*. 2009;454(2):189-194. doi:10.1007/s00428-008-0721-7
12. Dantey K, Cooper K. Myxoid solitary fibrous tumor: a study of three cases. *Int J Surg Pathol.* 2013;21(4):358-62. doi: 10.1177/1066896912470166.
13. de Saint Aubain Somerhausen N, Rubin BP, Fletcher CD. Myxoid solitary fibrous tumor: a study ofseven cases with emphasis on differential diagnosis. *Mod Pathol.* 1999;12(5):463-71.
14. Robinson DR, Wu YM, Kalyana-Sundaram S, et al. Identification of recurrent NAB2-STAT6 gene fusions in solitary fibrous tumor by integrative sequencing. *Nat Genet.* 2013;45(2):180-5. doi: 10.1038/ng.2509. E
15. Demicco EG, Fritchie KJ, Han A. Solitary fibrous tumor. In: WHO Classification of Tumours EditorialBoard. Soft tissue and bone tumours. Lyon (France): International Agency for Research on Cancer;2020. (WHO classification of tumours series, 5th ed.; vol. 3). *https://publications.iarc.fr/588.*, pp104-108
16. England DM, Hochholzer L, McCarthy MJ. Localized benign and malignant fibrous tumors of the pleura. A clinicopathologic review of 223 cases. *Am J Surg Pathol* 1989;13:640–658.
17. Enzinger FM, Smith BH . Hemangiopericytoma. An analysis of 106 cases. *Hum Pathol* 1976;7:61–82.
18. Fisher JH . Hemangiopericytoma: a review of twenty cases. *Can Med Assoc J* 1960;83:1136–1139.
19. Goldman SM, Davidson AJ, Neal J . Retroperitoneal and pelvic hemangiopericytomas: clinical, radiologic, and pathologic correlation. *Radiology* 1988;168:13–17.
20. Insabato L, Siano M, Somma A, *et al*. Extrapleural solitary fibrous tumor: a clinicopathologic study of19 cases. *Int J Surg Pathol* 2009;17:250–254.
21. Nielsen GP, O'Connell JX, Dickersin GR, *et al*. Solitary fibrous tumor of soft tissue: a report of 15cases, including 5 malignant examples with light microscopic, immunohistochemical, and ultrastructural data. *Mod Pathol* 1997;10:1028–1037.
22. Robinson LA. Solitary fibrous tumor of the pleura. *Cancer Control* 2006;13:264–269.

Case Report

NASAL FLOOR ELEVATION FOR REHABILITATION OF PRE-MAXILLA: A CASE REPORT

L. Tomaselli

Correspondence to:
Luigi Tomaselli, DDS, MS
Private practice,
Via Azzurra 26,
40138 Bologna, Italy
e-mail: gigitomaselli@gmail.com

ABSTRACT

Nasal floor elevation (NFE) is a surgical procedure performed in the maxillary region to create additional space for the successful placement of dental implants. This technique is commonly employed when there is insufficient bone height in the sub-nasal part of the maxilla, particularly in incisors and canines. During the procedure, the nasal membrane is lifted, and a bone graft material is placed in the resulting space between the periosteum and bone. This augmentation enhances bone volume, providing a stable foundation for immediate placement of dental implants. The NFE procedure aims to address limitations in bone height, ensuring that the implants can be securely anchored in the upper jaw. NFE is often recommended for individuals who have experienced bone loss due to factors such as tooth loss, periodontal disease, or trauma. Creating a more favorable environment for dental implant placement enables individuals to restore missing teeth in the pre-maxilla, ultimately improving oral function and aesthetics. NFE can be combined with pre-maxilla vestibular bone augmentation by means of guided bone regeneration. Successful integration of dental implants following NFE contributes to long-term stability and functionality in the upper jaw. Here we describe a case, and literature is discussed.

KEYWORDS: *nasal floor, elevation, augmentation, graft, implant, fixture*

INTRODUCTION

Pre-maxilla atrophy is a condition characterized by the loss of bone volume in the anterior maxillary region, presenting a significant challenge in implant dentistry. The primary cause often stems from the loss of natural teeth, leading to the resorption of alveolar bone in the pre-maxillary area. Chronic periodontal disease can contribute to bone loss, affecting the stability and volume of the maxillary bone. Facial trauma, particularly in the anterior maxilla, can result in bone loss and compromise the structure of the pre-maxillary region.

Pre-maxilla atrophy can result in facial changes and compromise facial aesthetics, impacting the patient's self-esteem and quality of life. Insufficient bone volume poses challenges for successful dental implant placement, requiring augmentation techniques to establish a stable foundation. Cone-beam computed tomography (CBCT) is a crucial tool for assessing bone volume, density, and the overall condition of the pre-maxillary region.

Thorough clinical evaluation, including assessing soft tissue quality and quantity, aids in determining the extent of pre-maxilla atrophy. Autogenous, allogeneic, or xenogeneic bone grafts may be employed to augment the pre-maxillary region, enhancing bone volume for implant placement. Membrane barriers and growth factors may be used to facilitate guided bone regeneration (GBR), enhancing the predictability of bone augmentation procedures.

Nasal floor elevation (NFE) via oral vestibulum is increasingly used in implant dentistry, explicitly addressing challenges associated with inadequate bone height in the anterior maxilla (1-8). The oral vestibulum approach leverages the anterior access point to the nasal floor. It is particularly indicated when atrophy in the pre-maxilla necessitates a

Received: 05 September 2022
Accepted: 29 September 2022

minimally invasive yet effective means of NFE for dental implant placement. This way, fixtures are inserted bi-cortically, getting a more stable grip on the bone. Only the implant tip emerged over the bony nasal floor and under the periosteum in a space filled with bone grafts.

A precise incision in the oral vestibulum provides access to the pre-maxillary, minimizing soft tissue trauma. Dissecting the periosteum is performed to access the nasal floor. The nasal membrane is gently elevated, creating a space for bone graft material. CBCT imaging is essential for evaluating maxillary anatomy, bone density, and nerve proximity, aiding in meticulous preoperative planning. Due to the proximity to the oral cavity, infection control is paramount. Strict adherence to aseptic techniques and appropriate postoperative care protocols are implemented to minimize the risk of complications. The potential for postoperative hematoma and swelling is mitigated through meticulous hemostasis and appropriate postoperative measures.

Studies have shown promising success rates for implants placed following nasal floor elevation via the oral vestibulum, emphasizing the procedure's effectiveness in providing a stable foundation for implant integration (1-8). The minimally invasive nature of this technique contributes to reduced patient discomfort and faster recovery. Here, we describe a case, and literature is discussed.

CASE REPORT

A 46-year-old man presented at our dental clinic requesting fixed oral maxillary rehabilitation. At the dental examination, the patient showed total upper and lower edentulism. A panoramic x-ray and a CTBT scan were performed. Before surgery, the patient was informed about the operative risk and complications, and written consent was obtained from the patient for publication of this case report and accompanying images. After local anesthesia with articaine, the vestibular and palatine mucosa was incised and detached until the maxilla was completely skeletonized (Fig. 1). Four implants were inserted in the maxillary residual bone after NFE (Fig. 2).

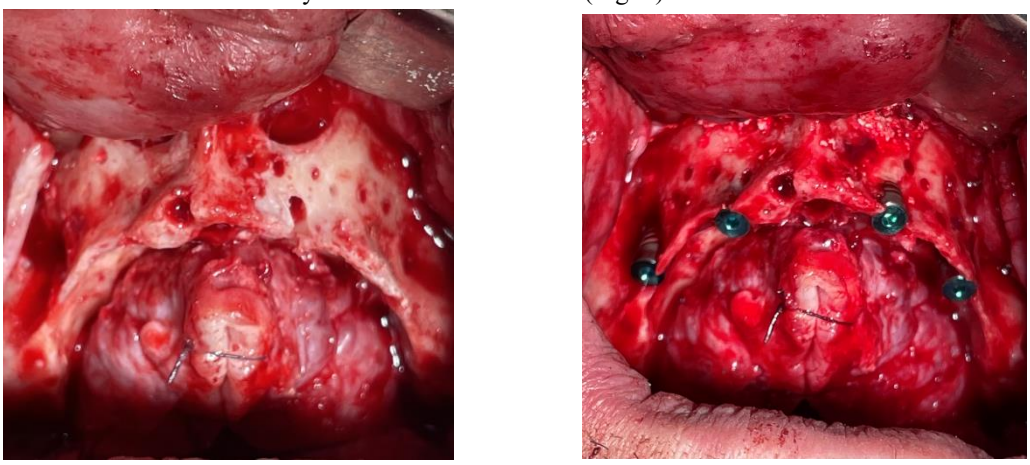


Fig. 1, 2. *Maxilla was skeletonized, and 4 implants were inserted in the maxillary residual crest after NFE with heterologous bone chips.*

NFE was performed with the placement of heterologous bone (Geistlich Bio-Oss®, Thiene VI, Italy) in both nasal cavities. In addition, a horizontal GBR was performed in the pre-maxilla region using heterologous bone, reinforced membranes, and fixed with pins (Fig. 3-5).

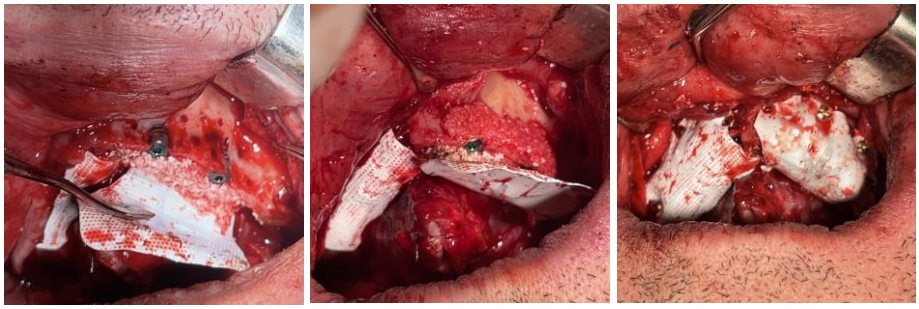


Fig. 3-5. *Horizontal GBR on the buccal side of pre-maxilla performed with heterologous bone and membranes fixed with pins in both sides of the upper jaw.*

Finally, the mucosa was sutured (Fig. 6), and a control CTCB scan was then performed (Fig. 7, 8). The CT scan highlights the NFE with the implants inserted into the heterologous bone (Fig. 8).

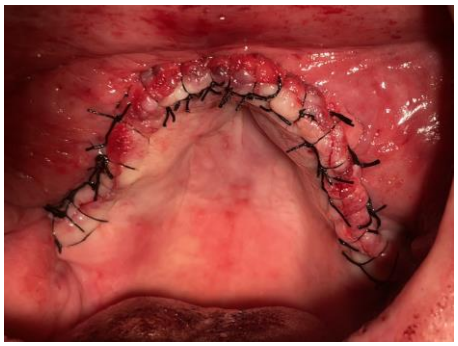


Fig. 6. *The upper oral mucosa is sutured.*

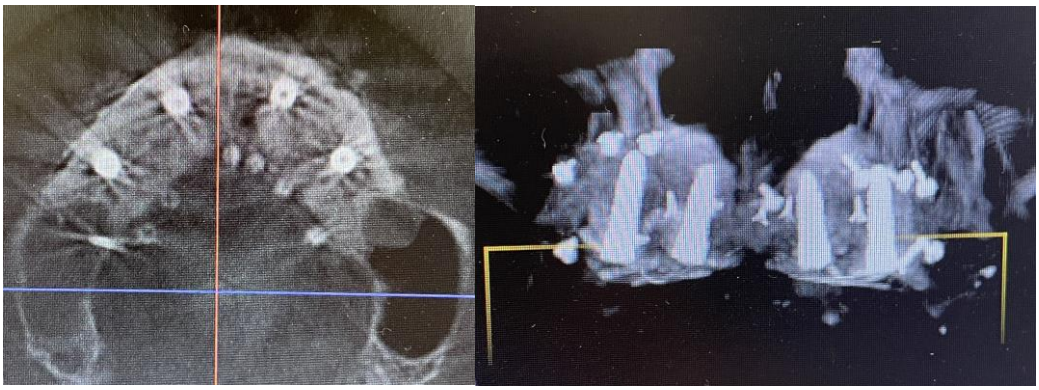


Fig. 7, 8. *Axial and vertical sections of CT scan. The vertical section of the CT scan highlights the NFE by inserting the implants into the heterologous bone.*

Six months after surgery, the maxillary mucosa was again incised and dissected, reinforced membranes removed, implants were uncovered by excess bone, and the healing screws screwed onto the implants (Fig. 9-12).

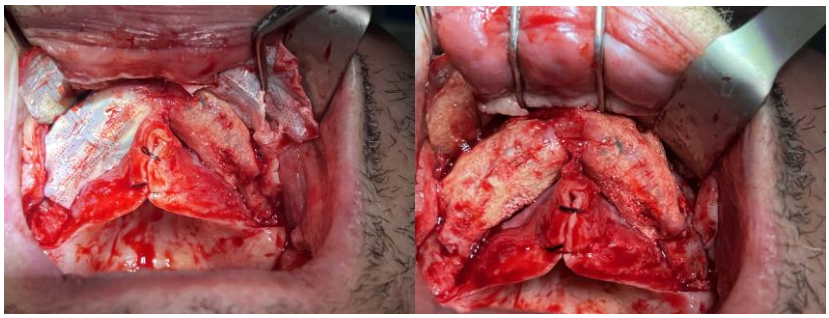


Fig. 9, 10. *Maxillary mucosa is incised and dissected, and reinforced membranes are removed.*

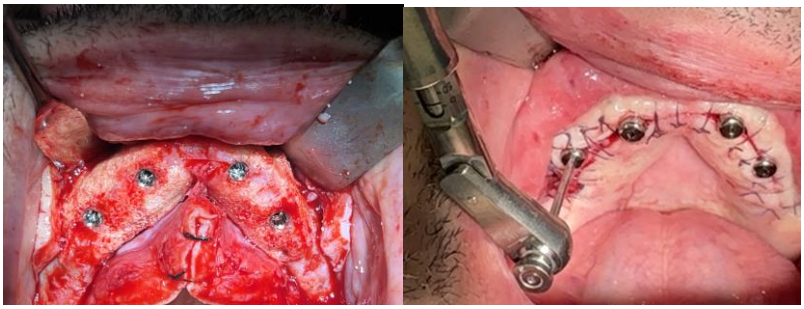


Fig. 11, 12. *Implants were uncovered by bone excess, and healing screws were inserted into the fixtures.*

In the following month, the mucosa appeared completely healed, and the implants could be loaded for prosthetic rehabilitation (Fig. 13-15).

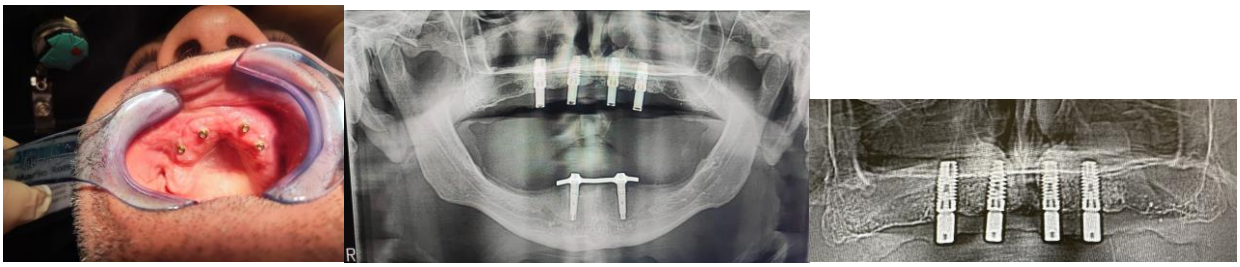


Fig. 13-15. *One month later, the mucosa appeared completely healed, and the implants were ready for prosthetic rehabilitation.*

DISCUSSION

Pre-maxilla bone augmentation is a critical aspect of implant dentistry, addressing challenges posed by bone atrophy in the anterior maxillary region. Pre-maxilla bone augmentation can be obtained with bone grafting techniques (9-12), NFE (1-8), and guided bone regeneration (13-17). Bone grafts can be autogenous (obtained from intraoral or extraoral donor sites, provide excellent osteogenic potential for augmenting the pre-maxilla region), or xenogeneic bone grafts (derived from animal sources) can offer alternatives for patients averse to autogenous grafts. In addition, allogeneic and synthetic materials are used with membranes to promote bone regeneration. Incorporating growth factors, platelet-rich plasma, and other biological adjuncts in bone grafting may accelerate healing and enhance graft integration.

Few reports regarding nasal floor augmentation (NFA) (1-8) are available. In 2012, El-Ghareeb et al. (1) evaluated the survival and success of dental implants placed in nasally grafted maxillae with osteoconductive bone substitutes. Six patients with entirely edentulous maxillae and inadequate height in the anterior to support implants underwent NFA. The nasal floor was exposed intraoral and grafted with osteoconductive bone graft substitutes. Twenty-four dental implants were placed, restored with a bar-retained implant-supported overdenture after a traditional healing period, and followed up after prosthetic loading for 14 months.

Bone levels were quantified radiographically based on a score ranging from 1 to 3, where 3 represented the highest bone support. Implants were evaluated for thread exposure and soft tissue health. They were considered successful if the following criteria were met: absence of mobility, lack of symptoms, and healthy peri-implant soft tissue without thread exposure. The implant survival rate was 100%, with no complications. Bone scores ranged from 2 to 3, with 87.5% of implants having a score of 3 and 12.5% having a score of 2. The authors concluded that osteoconductive bone substitutes for NFA are a reliable method for reconstructing the anterior atrophic maxilla for implant-supported overdentures.

Mazor et al. (2) performed a retrospective study on 32 consecutive patients in the same year. All patients presented with alveolar bone height deficiency in the anterior region, which was insufficient to place a dental implant according to a computed tomography scan before implantation. Elevation and augmentation of the nasal mucosa were performed simultaneously with dental implant placement. Patients received 100 implants inserted in conjunction with NFE. The average bone addition following NFA was 3.4 ± 0.9 mm detected by CT scan. The mean follow-up time was 27.8 ± 12.4 months, and during that follow-up period, no implant failure was recorded, resulting in 100% implant survival.

In 2014, Lorean et al. (3) investigated 67 patients. Two hundred and three implants were inserted in combination with NFE. The mean follow-up periods were 65.93 ± 13.2 months. The mean bone augmentation was 3.65 ± 0.9 mm with NFE. During the follow-up period, no implants were lost, resulting in a 100% survival rate.

In 2015, Garcia-Denche et al. (4) compared implants placed in augmented bone in the anterior maxilla using the NFE technique with implants placed in the maxillary sinus region using the sinus lift technique. A clinical trial was performed on 14 patients receiving 78 implants. The implants were assigned to one of two study groups based on implant location. Thirty-seven implants were placed in the nasal fossa region (NF group), and 41 implants were placed in the maxillary sinus region (MS group). Patients were followed up for 4.5 ± 2.2 years, with comparable follow-up times for implants in the NF and MS groups. The implant success rate was 89.2% in the NF group and 95.0% in the MS group, with no statistically significant difference. In addition, case reports of NFA were reported (5, 6).

Two systematic reviews are available. In 2003, Wallace et al. (7) obtained a weighted mean follow-up of 32.2 months from literature analysis and a weighted survival rate after this period of 97.64%. Authors concluded that implants placed after an NFE present a good survival and a low range of complications.

In 2012 Dasmah et al. (8) reviewed the existing scientific literature. Only nine studies fulfilled the eligibility criteria and were included in the qualitative synthesis. Of those nine studies, five were case reports, and four were comparative follow-up studies. In the included case reports, 14 implants were placed in five patients, with a survival rate of 100%. In comparison, 408 implants were placed in 130 patients, with survival rates ranging from 89% to 100% in included comparative follow-up studies. No complications were observed during follow-ups, and the patients were satisfied with the functional and aesthetic results of the treatment. The systematic review results indicate that implant placement using NFA techniques can be considered a predictable treatment modality.

Our case report shows that the surgical technique for NFE, implant insertion, and horizontal GBR using heterologous bone and reinforced membranes is a reliable technique.

CONCLUSIONS

Pre-maxilla atrophy poses significant challenges in implant dentistry, affecting the aesthetics and functional aspects of oral rehabilitation. Pre-maxilla bone augmentation involves a range of surgical techniques, each tailored to the specific needs of the patient and the complexity of the case. NFE via oral vestibulum represents a cutting-edge approach in implant dentistry. By creating a more favorable environment for dental implant placement, this procedure enables individuals to restore missing teeth in the pre-maxilla, ultimately improving oral function and aesthetics.

NFE can be combined with pre-maxilla vestibular bone augmentation by means of horizontal GBR. Successful integration of dental implants following NFE contributes to long-term stability and functionality in the upper jaw.

REFERENCES

1. El-Ghareeb M, Pi-Anfruns J, Khosousi M, Aghaloo T, Moy P. Nasal floor augmentation for the reconstruction of the atrophic maxilla: a case series. *J Oral Maxillofac Surg.* 2012;70(3):e235-41. doi: 10.1016/j.joms.2011.09.032.
2. Mazor Z, Lorean A, Mijiritsky E, Levin L. Nasal floor elevation combined with dental implant placement. *Clin Implant Dent Relat Res.* 2012 Oct;14(5):768-71. doi: 10.1111/j.1708-8208.2010.00312.x.
3. Lorean A, Mazor Z, Barbu H, Mijiritsky E, Levin L. Nasal floor elevation combined with dental implant placement: a long-term report of up to 86 months. *Int J Oral Maxillofac Implants.* 2014 ;29(3):705-8. doi: 10.11607/jomi.3565.
4. Garcia-Denche JT, Abbushi A, Hernández G, Fernández-Tresguerres I, Lopez-Cabarcos E, Tamimi F. Nasal Floor Elevation for Implant Treatment in the Atrophic Premaxilla: A Within-Patient Comparative Study. *Clin Implant Dent Relat Res.* 2015;17 Suppl 2:e520-30.
5. Rafael CF, Magrin GL, Morsch CS, Benfatti CAM, Volpato CÂM, Bianchini MAL. Nasal Floor Elevation with Simultaneous Implant Placement: A Case Report. *J Int Acad Periodontol.* 2016;18(3):94-100.
6. Sentineri R, Lombardi T, Celauro A, Stacchi C. Nasal Floor Elevation with Transcrestal Hydrodynamic Approach Combined with Dental Implant Placement: A Case Report. *Int J Periodontics Restorative Dent.* 2016;36(3):357-61. doi: 10.11607/prd.2540.
7. Wallace SS, Froum SJ. Effect of maxillary sinus augmentation on the survival of endosseous dental implants. A systematic review. *Ann Periodontol*. 2003;8(1):328-343. doi:10.1902/annals.2003.8.1.328
8. Dasmah A, Thor A, Ekestubbe A, Sennerby L, Rasmusson L. Particulate vs. block bone grafts: three-dimensional changes in graft volume after reconstruction of the atrophic maxilla, a 2-year radiographic follow-up. *J Craniomaxillofac Surg.* 2012;40(8):654-9.
9. Monje A, Monje F, Chan HL, Suarez F, Villanueva-Alcojol L, Garcia-Nogales A, Wang HL. Comparison of microstructures between block grafts from the mandibular ramus and calvarium for horizontal bone augmentation of the maxilla: a case series study. *Int J Periodontics Restorative Dent.* 2013;33(6):e153-61.
10. Dasmah A, Thor A, Ekestubbe A, Sennerby L, Rasmusson L. Marginal bone-level alterations at implants installed in block versus particulate onlay bone grafts mixed with platelet-rich plasma in atrophic maxilla. a prospective 5-year follow-up study of 15 patients. *Clin Implant Dent Relat Res.* 2013;15(1):7-14. doi: 10.1111/j.1708-8208.2011.00377.x.
11. Gulinelli JL, Dutra RA, Marão HF, Simeão SFP, Groli Klein GB, Santos PL. Maxilla reconstruction with autogenous bone block grafts: computed tomography evaluation and implant survival in a 5-year retrospective study. *Int J Oral Maxillofac Surg*. 2017;46(8):1045-1051.
12. Gultekin BA, Cansiz E, Borahan MO. Clinical and 3-Dimensional Radiographic Evaluation of Autogenous Iliac Block Bone Grafting and Guided Bone Regeneration in Patients With Atrophic Maxilla. *J Oral Maxillofac Surg.* 2017;75(4):709-722.
13. Tal H, Oelgiesser D, Moses O. Preimplant guided bone regeneration in the anterior maxilla. *Int J Periodontics Restorative Dent.* 1997;17(5):436-47.
14. Jiang X, Zhang Y, Di P, Lin Y. Hard tissue volume stability of guided bone regeneration during the healing stage in the anterior maxilla: A clinical and radiographic study. *Clin Implant Dent Relat Res.* 2018;20(1):68-75.

15. Li Y, Zhang XM, Qian SJ, Qiao SC, Lai HC, Shi JY. The influence of initial defect morphology of alveolar ridge on volumetric change of grafted bone following guided bone regeneration in the anterior maxilla region: an exploratory retrospective study. *Ann Transl Med.* 2020;8(23):1592.
16. Zhang L, Huang Y. Radiographic Evaluation of the Alveolar Ridge Splitting Technique Combined with Guided Bone Regeneration vs Guided Bone Regeneration Alone in the Anterior Maxilla: A Retrospective Controlled Study. *Int J Periodontics Restorative Dent.* 2021;41(5):751–759.
17. Chen H, Gu T, Lai H, Gu X. Evaluation of hard tissue 3-dimensional stability around single implants placed with guided bone regeneration in the anterior maxilla: A 3-year retrospective study. *J Prosthet Dent.* 2022 ;128(5):919-927.

Review

NEEDLE BREAKAGE DURING INFERIOR ALVEOLAR NERVE BLOCK ANESTHESIA: A REVIEW

F. Tricca[1†*], S.R. Tari[‡1], A. Signore[2], S. Benedicenti[2], S.A. Gehrke[3‡], F. Inchingolo[4†] and A. Scarano[1]

[1]Department of Innovative Technologies in Medicine and Dentistry, University of Chieti–Pescara, Chieti, Italy;
[2]Department of Surgical Sciences and Integrated Diagnostics, University of Genoa, Genoa, Italy;
[3]Department of Research, Bioface/PgO/UCAM, Montevideo, Uruguay, Department of Biotechnology, Universidad Católica de Murcia (UCAM), Murcia, Spain;
[4]Department of Interdisciplinary Medicine, Section of Dental Medicine, University of Bari "Aldo Moro", Bari, Italy

[†]These authors contributed equally to this work as co-first Authors.
[‡]These authors contributed equally to this work as co-last Authors.

**Correspondence to*:
Antonio Scarano, D.D.S., M.D.,
Department of Innovative Technologies in Medicine & Dentistry,
University of Chieti-Pescara,
Via Dei Vestini 31,
66100 Chieti Italy
e-mail: ascarano@unich.it

ABSTRACT

Needle breakage is a frustrating accident during inferior alveolar nerve block administration. Proper treatment of such a complication is fundamental considering that, without an appropriate localization, the fragment manipulation may worsen the condition and lead to a deeper migration into vital structures. This review examines in depth the potential risk factors of needle breakage, analyzing the proper management and treatment of such conditions. Preventive measures are also proposed to decrease the risk of breakage. Changing the needle direction is only allowed if most of the needle is withdrawn with the tip just beneath the mucosa. The use of a bidirectional rotation insertion technique during the administration could be another measure to minimize needle deflection. Repeated injections with the same needle, should be avoided since they increase fragility and susceptibility to fracture. Needles and syringes should be checked for irregularities before the injection. Furthermore, adequate preoperative sedation should be considered, especially in pediatric patients, to achieve proper compliance. After carefully evaluating the entry point, if the fragment is still visible, an immediate attempt to retrieve it with fine artery forceps is required. When the needle is completely covered by the mucosa, the retrieval becomes complex and unproper maneuvers may lead to a further displacement into deeper tissues.

KEYWORDS: *needle breakage, IAN, inferior alveolar nerve, anesthesia*

INTRODUCTION

Modern disposable hypodermic needles were introduced only in the second half of the 20th century. Previously, available reusable needles were made of carbon steel. These needles required sharpening and sterilization after each use, and the risk of breakage due to metal fatigue represented a frequent complication (1). Nowadays, scientific advances

Received: 09 September 2022
Accepted: 02 October 2022

in metallurgy, enhanced training in anesthesia, and the introduction of modern disposable hypodermic needles have largely decreased the risk of breakage.

A 50-year retrospective analysis conducted by Augello et al. (2) revealed that, in most of cases, needle breakage occurred during inferior alveolar nerve block administration (70 %, 45 patients out of 64). Pogrel (1), based on data from North California dentists, reported an estimated risk of 1 case out of 14 million for each inferior alveolar nerve block administered.

The success rate of the inferior alveolar nerve block anesthesia is relatively low when compared to other techniques, with a failure rate up to 30 % (3). Kroman et al. (4) demonstrated that a deep penetration of the needle, up to 21 mm, is necessary for optimal anesthesia. Proper diffusion of the anesthetic solution into the pterygomandibular space (Fig.1) should be considered when analyzing failures, and perineural tissue differences have shown a profound impact on the onset time of analgesia (5).

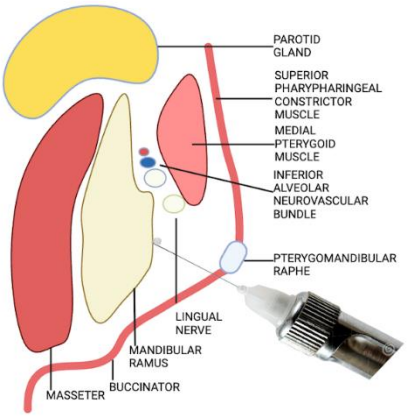


Fig. 1. *The pterygomandibular space is defined by the medial surface of the ramus laterally, medial pterygoid muscle and associated fascia medially, lateral pterygoid muscle superiorly, parotid gland posteriorly and pterygomandibular raphe, buccinator and superior constrictor muscles anteriorly.*

Various approaches have been proposed in order to increase the effectiveness and reliability of such techniques. Malamed has provided a thorough description of the conventional injection technique (6). In this technique, the pterygomandibular raphe and other landmarks, such as the coronoid notch, are used to locate the exact position of the nerve as it enters the mandibular foramen. The medial surface of the ramus and the pterygomandibular raphe outline the proper injection site. With the syringe barrel located at the opposite side (premolars teeth) and kept parallel to the mandibular plane, the coronoid notch is palpated. Drawing an imaginary line from the fingertip to the deepest portion of the pterygomandibular raphe, the location for the needle insertion is defined at one-quarter of this distance, towards the pterygomandibular raphe. At this point, the needle is inserted 20/25 mm until bone is gently contacted and the solution is deposited. Despite the clearness of the procedure, the general difficulty encountered in retrieving the anatomical landmarks, has brough clinicians to develop other strategies. An alternative technique has been proposed by Thangavelu et al. (7). With the needle penetration site located 6/8 mm above and 8/10 mm posterior to the coronoid notch, the barrel of the syringe is oriented towards the contralateral premolars. From this point, the needle is advanced until bone is reached. Touching the medial side of the ramus (used as a guide), the barrel is further adjusted towards the midline and, after 21/24 mm of penetration, readjusted to the opposite side to reach the area above the inferior alveolar nerve entry in the mandibular canal. Frequent contact of the periosteum with the tip of the needle is a constant of this technique, which has been reported to achieve a success rate of up to 95 %. Palti et al. (8) proposed specific landmarks on the mandibular molars for identifying the optimal injection site, while Suazo et al. (9) proposed an alternative injection site represented by the retromolar triangle. Other different techniques include the Gow-Gates technique (10), the Vazirani-Akinosi nerve block (11), and the Fischer 1-2-3 technique (or indirect technique) (12).

When a needle breakage occurs, and the fragment is buried in the soft tissues, retrieval surgery should be performed to avoid life-threatening complications resulting from the potential migration of the needle. The limited access and proximity to vital structures represent a challenge for surgeons (13). The surgical procedure is typically unpredictable, and a complete analysis based on 3D imaging is needed to assess the best surgical approach (14).

Electromagnets, as long as iron has been eliminated from stainless steel alloys, are no longer effective for detecting fragments (15). 3D imaging (CT and CBCT) represents the gold standard for properly evaluating the needle position and planning the best retrieval procedure. However, 2D techniques may be useful tools, such as plain films (16) or C-arm fluoroscopy (17, 18). Due to the difficulties encountered in properly locating fragments during the intraoperative retrieval procedure, these latter are often considered valid and complementary to 3D imaging (19, 20). The main advantages of these techniques are the rapid intraoperative collection and review of images without disturbing reference needles, along with a general reduction of radiation dose and excellent image quality (17, 19). Recent innovations in computer-assisted surgery through navigation systems have hugely improved the clinical results (21). Navigation system technologies are primarily used in neurosurgery or cranial base surgery. The dynamic nature of the mandible and surrounding soft tissues represents an important limitation. However, using customized 3D-printed mouth openings or interocclusal splints during image acquisition and surgical procedures effectively matches the imaging data with the

patient's actual position (13, 20-23). Intraoperative ultrasounds have also been proposed for detecting foreign bodies in soft tissues (24). However, accuracy and size are the main limitations to their use.

The aim of this review is to investigate the most influential risk factors related to needle breakage, assess the dynamics related to this occurrence, describe the most used retrieval strategies, and provide preventive measures and guidelines for properly managing such a complication.

MATERIALS AND METHODS

This review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement. The main research questions were captured in the PICO (Population, Intervention, Comparison, Outcomes) format: “What are the main risk factors related to needle breakage during an inferior alveolar nerve block, and how can this event be avoided?” Is it possible to define a proper management of such complications?" An electronic search was conducted on the PUBMED /MEDLINE bibliographic database (PubMed). 36 articles with a period from 1960 to 2021 were selected using the following algorithm:

- "needle" AND ("fractured" OR "broken" OR "breakage") AND ("inferior alveolar nerve block" OR" inferior alveolar nerve anesthesia “OR "pterygomandibular space").

Due to comprehensive details about the analyzed complication, case series, and case reports were chosen as the primary source for this review. Titles and abstracts of articles were subjected to an initial selection process, considering relevance, type of study, and population. A hand search was conducted for the resulting studies by analyzing complete articles and their relevance and adherence to inclusion criteria.

Data extraction/analysis

From the selected studies were extracted the following data: patient age, needle size, timing (from the accident to the treatment), migration sites, reported cause of fracture, symptoms, and surgical technique performed for the retrieval.

Data were collected and analyzed using Microsoft Office Excel 2007© (Microsoft Cooperation, München, Germany). The descriptive analysis included 27 articles.

RESULTS

Needle type/ symptoms reported

Data analysis showed that needle size varied from 27 to 30 G, with the latter being the most commonly used. Needle length varied from 21 mm (21, 25) to 40 mm (17). Patient ages ranged from 3 (26) to 65 (27).

The most reported cause of needle breakage was abrupt movement of both operator or patient, and in the majority of cases, needle breakage occurred in the hub portion. Improper techniques (15) and management (double bending, reutilization) of the needle (27), or a combination of these (28, 21) represented other important factors related to an increased risk.

At the initial consultation, trismus and generalized pain during mandibular movements were the most reported symptoms. Other symptoms, such as otalgia (27, 29) or reduced head movement (30), result from the migration of the fragments.

Timing/ migration sites

Due to the potential risks derived from fragment migration, the time between the incident and the retrieval intervention should be as short as possible. Studies have considered treatment intervals ranging from several days to months (30) or even years (22).

The retrieval surgery may represent a severe risk for neurological or tissue damage (31). Some authors suggested leaving the fragment in situ as long as the patient is asymptomatic (22), since the formation of scar tissue and fibrosis could play a fundamental role in preventing further displacements. However, effective stabilization is hardly achievable (27), and the fragment migration itself represents a potential trigger for trismus, infections, paresthesia, or hemorrhage, in addition to psychological trauma (29).

Significant migration sites reported included the perivertebral space (30), vascular structures (28), parotid space (17), posterior cervical space (19), parapharyngeal space (29), pterygoid muscles (13, 22), and the external auditory canal (29).

Retrieval surgery

Although general anesthesia was typically administered to most patients, in some cases, only local anesthesia was used (32, 14).

It is important to note that during the surgery procedures, the needle may be further dislocated (33) into the soft tissues. This further complication may worsen the condition and jeopardize the retrieval (19). Some studies reported that previous failed attempts to retrieve the fragments (17, 19) have contributed to further migration.

When the fragment is located in the pterygomandibular area, two are the main surgical approaches: a vertical incision on the medial aspect of the mandible followed by blunt sopra-periosteal dissection, or a parallel incision to the external oblique ridge followed by a subperiosteal dissection. This latter approach provides a better identification and protection of the inferior alveolar and lingual nerve and is generally preferable (20). Incisions close to the fragment in the lingual aspect are generally contraindicated (33).

Intraoperative navigation systems with 3D-printed templates or interocclusal splints showed to be effective and reliable tools for the retrieval. A proper machine calibration enables a more precise detection of the fragments, leading to a significant decrease in both operative time and invasiveness of the procedures (20-23).

Extraoral approaches such as endaural approach (29), neck explorations via open transcervical approach (30) and incision along the lower border of the mandible (28) were also reported. A spontaneous extrusion (27) was also observed.

DISCUSSION

Needle breakage during inferior alveolar nerve block anesthesia is a rare but unpleasant complication. Despite the improvement of the alloys and the transition to disposable stainless steel hypodermic needles, needle fracture is still present. Catelani et al. (34) reported cases in which manufacturing defects were the leading cause of breakage. However, improper injection techniques, patient movements or wrong choice of the needle, rather than material defects, should be considered.

Augello et al. (2) highlighted that the use of 30 G needles, based on the incorrect belief that a thinner needle reduces pain, was related to a higher risk of breakage. As reported by Fuller and Moller, there were no significant differences in pain perception when 25, 27, and 30 G needles were compared (35, 36). Moreover, the injection pressure increases as the needle diameter decreases (33). A higher injection rate is also linked to increased pressure and, thus pain, with subsequent abrupt movement of the patient and increased risk for needle breakage. Other factors, such as periosteal contact or excessive proximity of the tip to the nerve, can lead to similar results (33). From data derived from the descriptive analysis, some preventive measures can be proposed (Table I).

Table I. *Preventive measures.*

PREVENTIVE TIPS
Use a 27 G long needles; avoid 30 G needles
Avoid bending the needle
Avoid inserting the needle up to its hub. Leave at least 5 mm outside the tissue
Avoid position changes during administration
Avoid repeated injections; needles should be replaced after every use
Use of bidirectional rotation insertion technique

The use of 30 G needles when administering inferior alveolar nerve blocks (19) is not recommended. Since the hub-needle junction represents the most delicate and rigid part, a full insertion is also contraindicated (37), and it is advisable to use long needles instead of short ones (21, 38). Bending the needle is also not recommended, as it weakens the structure. Changing the direction of the syringe when the needle is inserted into deeper tissues produces similar results (33). This procedure is only allowed if most of the needle is withdrawn, with the tip just beneath the mucosa (39). Using the bidirectional rotation insertion technique during administration could be another measure to minimize needle deflection (31, 40). Moreover, repeated injections with the same needle should be avoided since they increase fragility and susceptibility to fracture (41). Needles and syringes should be checked for irregularities before the injection (26), and adequate preoperative sedation with anxiolysis procedures (e.g., nitrous oxide-oxygen sedation) may be considered, especially in pediatric patients (25), to achieve proper compliance.

An immediate removal is generally recommended when breakage occurs, to avoid further complications. Acham et al., analyzing the literature from 1980 to 2018, reported an immediate removal within one day in 53.8% of cases, 30.8 % within 3 months, and 12.8% delayed 3-12 months or later (42). In this context, the case reported by Brooks and Murphy (43) was noteworthy. In a relatively short time, the fragment migrated from the pterygomandibular space to the jugular foramen, transecting the internal carotid artery and requiring prompt cerebrovascular intervention. The authors postulated that the

cutting bevel of the needle and the contraction of the nasopharynx and oropharynx musculature facilitated such a rapid and extensive migration (43).

Proper management and treatment of such conditions are fundamental for the clinician. After carefully evaluating the entry point, an immediate attempt to retrieve the fragment with fine artery forceps is required if the fragment is still visible.

If the needle is not clinically detectable, it is mandatory to reassure and adequately inform the patient to avoid excessive jaw movements, which may trigger fragment movement and migration into adjacent structures (44). Chewing and swallowing may also contribute to further migration, potentially damaging the maxillary artery, internal carotid artery, internal jugular vein, or cranial nerves (glossopharyngeal, vagus, and hypoglossal nerve) (29). Attempts to palpate the mucosa are also not recommended since they may complicate the retrieval (33), leading to further dislocation into deeper tissues. The patient should be immediately referred to the local maxillofacial unit, and the remainder of the needle should be preserved for further analysis and assessment.

The rapidity of injection is also linked to pressure increase and thus pain, leading to possible abrupt movements of the patient and increased risk for needle breakage. Periosteal touching and excessive proximity of the needle at the nerve can represent a potential trigger for pain and so involuntary movement (19).

Due to the risk of dislocation into deeper tissues, generating a life-threatening condition, proper management and treatment are fundamental for the operator. They must be conducted using explorative surgery and previous clinical and radiographic evaluation. Timing of surgical removal is also a fundamental issue and must be minimized to prevent complications. Acham et al., analyzing the literature from 1980 to 2018, reported an immediate removal within one day in 53.8% of cases, 30.8 % within 3 months, and 12.8% delayed 3-12 months or later (38). After analyzing all the clinical reports, some preventive measures can be proposed.

It is not recommended to use a 30G needle when administering inferior alveolar nerve blocks (24). Provided that the hub-needle junction represents the most delicate and rigid part, a full insertion is neither recommended nor recommended (39), and it is advisable to use long instead of short needles (29, 33).

Bending the needle is also not recommended, as it weakens the needle as long as the grip and the direction of the syringe are changed when the needle is inserted into deeper tissues (19). Changing the needle direction is only allowed if most of the needle is withdrawn with the tip just beneath the mucosa (40). Using a bidirectional rotation insertion technique during administration could be another tip to minimize needle deflection (26, 41).

Repeated injections with the same needle should be avoided since they increase needle fragility and susceptibility to fracture (42). Needles and syringes should be checked for irregularities before the injection (16). Furthermore, adequate preoperative sedation or the use of oxide/oxygen analgesia/anxiolysis should be considered, especially in pediatric patients (43), to achieve proper compliance. If the fragment is still visible, an immediate attempt at retrieval is required with fine artery forceps after carefully evaluating the entry point. If the needle is not clinically detectable, it is mandatory to reassure and adequately inform the patient to avoid excessive jaw movements to limit the needle's migration (1). Chewing and swallowing may also contribute to the migration and cause potential damage to the maxillary artery, internal carotid artery, internal jugular vein, or cranial nerves (glossopharyngeal, vagus, and hypoglossal nerve) (27).

Palpating the mucosa is not recommended since it could complicate retrieval (19), leading to a further dislocation into deeper tissues. It is mandatory to immediately refer to the local maxillofacial unit and accurately describe the incident. Furthermore, sending the remainder and a new, fresh needle to the same unit and informing the dental defense company is advisable.

CONCLUSIONS

Even if a rare complication, needle breakage can be a traumatic event for both patient and clinician. Practitioners must know that immediate and adequate management is necessary if such a complication occurs. Before every injection, some preventive measures should be considered to minimize the risk of breakage. If the fragment is still visible, an immediate attempt to retrieve it is required. However, when the needle is completely covered by the mucosa, the retrieval becomes complex, and improper maneuvers may lead to a further displacement into deeper tissues. In such cases, the patient should be referred to the maxillofacial unit as soon as possible. Special care should be taken during administration in pediatric patients.

REFERENCES

1. Pogrel MA. Broken local anesthetic needles: a case series of 16 patients, with recommendations. *Journal of the*

American Dental Association 2009;140(12):1517-1522. doi:https://doi.org/10.14219/jada.archive.2009.0103
2. Augello M, von Jackowski J, Grätz KW, Jacobsen C. Needle breakage during local anesthesia in the oral cavity--a retrospective of the last 50 years with guidelines for treatment and prevention. *Clinical Oral Investigations*. 2011;15(1):3-8. doi:https://doi.org/10.1007/s00784-010-0442-6
3. Kanaa MD, Whitworth JM, Corbett IP, Meechan JG. Articaine buccal infiltration enhances the effectiveness of lidocaine inferior alveolar nerve block. *International Endodontic Journal*. 2009;42(3):238-246. doi:https://doi.org/10.1111/j.1365-2591.2008.01507.x
4. Kronman JH, el-Bermani AW, S Wongwatana, Kumar A. Preferred needle lengths for inferior alveolar anesthesia. *Gen Dent*. 1994;42(1):74-76.
5. Okamoto Y, Takasugi Y, Moriya K, Furuya H. Inferior alveolar nerve block by injection into the pterygomandibular space anterior to the mandibular foramen: radiographic study of local anesthetic spread in the pterygomandibular space. *Anesth Prog*. 2000;47(4):130-133.
6. The Dental Box. Inferior Alveolar Nerve Block. YouTube. Published April 3, 2020. https://www.youtube.com/watch?v=ceseuuStwxI
7. Thangavelu K, Kannan R, Kumar Ns. Inferior alveolar nerve block: Alternative technique. *Anesthesia: Essays and Researches*. 2012;6(1):53. doi:https://doi.org/10.4103/0259-1162.103375
8. Palti DG, Almeida CM de, Rodrigues A de C, Andreo JC, Lima JEO. Anesthetic technique for inferior alveolar nerve block: a new approach. *Journal of applied oral science: revista FOB*. 2011;19(1):11-15. doi:https://doi.org/10.1590/s1678-77572011000100004
9. Suazo Galdames Ic, Cantín López Mg, Zavando Matamala Da. Inferior alveolar nerve block anesthesia via the retromolar triangle, an alternative for patients with blood dyscrasias. *Med Oral Patol Oral Cir Bucal*. 2008;13(1):E43- 7.
10. Gow-Gates GA. Mandibular conduction anesthesia: a new technique using extraoral landmarks. Oral Surg Oral Med Oral Pathol. 1973 Sep;36(3):321-8. doi: 10.1016/0030-4220(73)90208-9.
11. Akinosi JO. A new approach to the mandibular nerve block. Br J Oral Surg. 1977 Jul;15(1):83-7. doi: 10.1016/0007-117x(77)90011-7.
12. Malamed SF. "Techniques of mandibular anesthesia". In: Handbook of local anesthesia, 4th edition. Harcourt Brace, Noida (1997): 228-234.
13. Gerbino G, Zavattero E, Berrone M, Berrone S. Management of Needle Breakage Using Intraoperative Navigation Following Inferior Alveolar Nerve Block. *Journal of Oral and Maxillofacial Surgery*. 2013;71(11):1819-1824. doi:https://doi.org/10.1016/j.joms.2013.07.023
14. Kim JH, Moon SY. Removal of a broken needle using three-dimensional computed tomography: a case report. *Journal of the Korean Association of Oral and Maxillofacial Surgeons*. 2013;39(5):251-251. doi:https://doi.org/10.5125/jkaoms.2013.39.5.251
15. Rifkind JB. Management of a broken needle in the pterygomandibular space following a Vazirani-Akinosi block: case report. *Journal - Canadian Dental Association*. 2011;77:b64-b64.
16. Bump RL, Roche WC. A broken needle in the pterygomandibular space. *Oral Surgery, Oral Medicine, Oral Pathology*. 1973;36(5):750-752. doi:https://doi.org/10.1016/0030-4220(73)90149-7
17. Nezafati S, Shahi S. Removal of broken dental needle using mobile digital C-arm. *Journal of Oral Science*. 2008;50(3):351-353. doi:https://doi.org/10.2334/josnusd.50.351
18. Margolis A, Loparich A, Raz E, Fleisher KE. Use of Intraoperative Biplanar Fluoroscopy for Minimally Invasive Retrieval of a Broken Dental Needle. *Journal of Oral and Maxillofacial Surgery*. 2020;78(11):1922-1925. doi:https://doi.org/10.1016/j.joms.2020.07.004
19. Altay MA, Jee-Hyun Lyu D, Collette D, et al. Transcervical migration of a broken dental needle: a case report and literature review. *Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology*. 2014;118(6):e161-e165. doi:https://doi.org/10.1016/j.oooo.2014.04.001
20. Hamzani Y, Rosenfeld E, Chaushu G, Yahya BH. Is intraoperative navigation for needle breakage mandatory? *The Journal of the American Dental Association*. 2019;150(2):154-158. doi:https://doi.org/10.1016/j.adaj.2018.09.007
21. Lukas D, Jan M, Politis Constantinus, Paul L. Fractured Needle Removal With a 3-Dimensionally Printed Surgical Guide: A Case Report and Literature Review. *Journal of Oral and Maxillofacial Surgery*. 2021;79(5):1019-1024. doi:https://doi.org/10.1016/j.joms.2020.11.002
22. Lee TYT, Zaid WS. Broken dental needle retrieval using a surgical navigation system: a case report and literature review. *Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology*. 2015;119(2):e55-e59. doi:https://doi.org/10.1016/j.oooo.2014.08.019
23. Stein K. Use of Intraoperative Navigation for Minimally Invasive Retrieval of a Broken Dental Needle. *Journal of Oral and Maxillofacial Surgery*. 2015;73(10):1911-1916. doi:https://doi.org/10.1016/j.joms.2015.04.033
24. Abe K, Nakamatsu K, Beppu K, Ariji E, Oka M. Use of intra-operative ultrasonography to detect a small foreign body in the soft tissue of the upper lip. Br Dent J. 1994 Oct 22;177(8):292-4. doi: 10.1038/sj.bdj.4808589.
25. Bagattoni S, D'Alessandro G, Marzo G, Piana G. Needle breakage during an inferior alveolar nerve block in a child with KBG syndrome: A case report. *European Archives of Paediatric Dentistry*. 2018;19(2):125-128.

doi:https://doi.org/10.1007/s40368-018-0336-x

26. Marks RB, McDonald S, Carlton DM. Management of a broken needle in the pterygomandibular space: report of case. *The Journal of the American Dental Association*. 1984; 109(2):263-264. doi:https://doi.org/10.14219/jada.archive.1984.0355
27. Rahman N, Clarke M, Stassen LFA. Case report: management of broken dental needles in practice. *J Ir Dent Assoc*. 2013;59(5):241-245.
28. Queiroz SBF de, Lima VN de, Amorim PHGH, Magro-Filho O, Amorim RFB. Retrieval of a Broken Dental Needle Close to the Facial Artery After Cervical Migration. *Journal of Craniofacial Surgery*. 2016;27(4):e338-e340. doi:https://doi.org/10.1097/scs.0000000000002507
29. Ribeiro L, Ramalho S, Gerós S, Coimbra Ferreira E, Faria A, Condé A. Needle in the external auditory canal: an unusual complication of inferior alveolar nerve block. *Oral Surgery Oral Medicine Oral Pathology and Oral Radiology*. 2014;117(6):e436-e437. doi:https://doi.org/10.1016/j.oooo.2013.09.014
30. Sahin B, Yildirimturk S, Sirin Y, Basaran B. Displacement of a Broken Dental Injection Needle Into the Perivertebral Space. *Journal of Craniofacial Surgery*. 2017;28(5):e474-e477. doi:https://doi.org/10.1097/scs.0000000000003781
31. Malamed SF. Handbook of Local Anesthesia. EU Elsevier Health. Published 2019. https://www.eu.elsevierhealth.com/handbook-of-local-anesthesia-9780323676861.html?nosto=nosto-page-search1
32. You J, Kim SG, Oh JS, Choi HI, Jih MK. Removal of a fractured needle during inferior alveolar nerve block: two case reports. *Journal of Dental Anesthesia and Pain Medicine*. 2017;17(3):225. doi:https://doi.org/10.17245/jdapm.2017.17.3.225
33. Zeltser R, Cohen C, Nardi Casap. The implications of a broken needle in the pterygomandibular space: clinical guidelines for prevention and retrieval. *Pediatr Dent*. 2002;24(2):153-156.
34. Catelani, Valente A, Rossi A, R Bertolai. Broken anesthetic needle in the pterygomandibular space. Four case reports. *Minerva Stomatol*. 2013;62(11-12):455-463.
35. Mollen AJ, Ficara AJ, Provant DR. Needles--25 gauge versus 27 gauge--can patients really tell? *Gen Dent* . 1981;29(5):417-418.
36. Fuller NP, Menke RA, Meyers WJ. Perception of pain to three different intraoral penetrations of needles. *Journal of the American Dental Association (1939)*. 1979;99(5):822-824. doi:https://doi.org/10.14219/jada.archive.1979.0384
37. Ethunandan M, Tran AL, Anand R, Bowden J, Seal MT, Brennan PA. Needle breakage following inferior alveolar nerve block: implications and management. *British Dental Journal*. 2007;202(7):395-397. doi:https://doi.org/10.1038/bdj.2007.272
38. Malamed SF, Reed K, Poorsattar S. Needle Breakage: Incidence and Prevention. *Dental Clinics of North America*. 2010;54(4):745-756. doi:https://doi.org/10.1016/j.cden.2010.06.013
39. Shah A, Mehta N, Von Arx DP. Fracture of a Dental Needle during Administration of an Inferior Alveolar Nerve Block. *Dental Update*. 2009;36(1):20-25. doi:https://doi.org/10.12968/denu.2009.36.1.20
40. Kennedy SC, Reader A, Nusstein J, Beck M, Weaver JM. The Significance of Needle Deflection in Success of the Inferior Alveolar Nerve Block in Patients with Irreversible Pulpitis. *Journal of Endodontics*. 2003;29(10):630-633. doi:https://doi.org/10.1097/00004770-200310000-00004
41. Fitzpatrick B. The broken dental needle. *Australian Dental Journal*. 1967;12(3):243-245. doi:https://doi.org/10.1111/j.1834-7819.1967.tb04267.x
42. Acham S, Truschnegg A, Rugani P, et al. Needle fracture as a complication of dental local anesthesia: recommendations for prevention and a comprehensive treatment algorithm based on literature from the past four decades. *Clinical Oral Investigations*. 2018;23(3):1109-1119. doi:https://doi.org/10.1007/s00784-018-2525-8
43. Brooks J, Murphy MT. A novel case of a broken dental anesthetic needle transecting the right internal carotid artery. *The Journal of the American Dental Association*. 2016;147(9):739-742. doi:https://doi.org/10.1016/j.adaj.2016.03.014
44. Tomaszewska IM, Graves MJ, Lipski M, Walocha JA. Anatomy and variations of the pterygomandibular space. Anatomical Variations in Clinical Dentistry. Published 2019. https://api.semanticscholar.org/CorpusID:10974361

Technical Note

VERTICAL RIDGE OF ATROPHIC MANDIBLES WITH SANDWICH OSTEOTOMY WITHOUT MINI-SCREWS AND MINI-PLATES: A TECHNICAL NOTE

A. Scarano[1,2], F. Tricca1, G. Falisi[3], and C. Bugea[1]

[1]Department of Innovative Technologies in Medicine & Dentistry, University of Chieti-Pescara, Italy;
[2]Visiting professor, Department of Oral Implantology, Dental Research Division, College Ingà, UNINGÁ, Cachoeiro de Itapemirim, Espirito Santo, Brazil;
[3]Department of Interdisciplinary Medicine, University of Bari "Aldo Moro", Bari, Italy

**Correspondence to*:
Antonio Scarano, D.D.S., M.D.,
Department of Innovative Technologies in Medicine & Dentistry,
University of Chieti-Pescara,
Via Dei Vestini 31,
66100 Chieti Italy
e-mail: ascarano@unich.it

ABSTRACT

The insufficient height and width of the edentulous alveolar ridge can complicate the implant rehabilitation of the posterior mandible. The aim of this technical note is to describe an inlay technique without the use of mini-screws and miniplates for the stabilization of the transported bone fragments. The inlay technique involves the first horizontal osteotomy performed 2-3 mm above the mandibular canal, and two oblique cuts are made using an ultrasonic device. The final phase of the vertical augmentation is performed with a dedicated instrument. The space between basal bone and coronal osteotomies segment is maintained by a hard equine block. The residual space is filled by particles of cortical-cancellous equine bone. This technique showed that equine collagenated blocks presented higher stability, allowed the elimination of the use of mini-screws and miniplates, and simplified the sandwich technique.

KEYWORDS: *inlay, regeneration, graft, augmentation, bone*

INTRODUCTION

The extensive loss in the posterior mandible presents a complex case for implant placement (1). For patients with extensive resorption, vertical augmentation of the alveolar ridge is necessary. Different regenerative techniques are currently utilized to achieve good bone volume for the predictable placement of endosseous implants in such cases.

Different surgical approaches are proposed, such as autogenous bone grafts, alloplastic materials (2-5), alveolar distraction osteogenesis, and recently inlay technique (6). Vertical bone regeneration in posterior mandibles with onlay bone grafts has been used, but the results have not been promising (7).

Guided bone regeneration was proposed in a 1991 report by Dahlin and colleagues (8). Expanded polytetrafluoroethylene membranes were proposed for posterior mandibular reconstruction and have been used with a high success rate (9, 10). However, vertical augmentation is a highly sensitive technique, predictable only when the surgical protocol is followed strictly (11). Also, titanium mesh and autogenous bone grafts have been used successfully

Received: 27 August 2022
Accepted: 22 September 2022

for vertical ridge augmentation of the atrophic maxilla and mandible and have gained popularity since their introduction (12, 13).

Titanium screws must fix the titanium mesh used, and infection is a common complication that may cause loss of grafted bone, resulting in failure. The inlay, which uses a bone block graft positioned between osteotomized bony segments, was developed by Schettler (14) in 1974. Stoelinga and colleagues (15) combined the visor osteotomy and sandwich techniques to augment the severely atrophic edentulous mandible with success. However, this technique involves donor site morbidity (16), as autogenous bone is used as the interpositional material.

The following technical note describes the protocol for alveolar ridge augmentation by a sandwich osteotomy combined with an interpositional xenograft without using mini-screws and miniplates to stabilize the transported bone fragments.

TECHNICAL NOTE

After a paracrestal incision in the buccal vestibule, avoiding with care the emergence of the mental nerve and a subperiosteal tissue dissection limited to the buccal side, a horizontal osteotomy is performed 2-3 mm above the mandibular canal, and two oblique cuts are made using an ultrasonic device (Surgysonic, Esacrom, Imola Italy). The final phase of the osteotomy is performed with a lever for dental extraction. The osteotomized segment is then raised in the coronal direction, sparing the lingual periosteum. Two miniblocks of equine bone (OsteoBiol Sp-Block, Tecnoss, Coazze, Italy) are inserted between the coronal osteotomized segment and the mandibular basal bone (Fig. 1). Particles of cortical-cancellous porcine bone filled the residual space. After periosteal releasing incisions, the flap is sutured carefully with Vicryl 4.0 (Ethicon FS-2; St. Stevens-Woluwe, Belgium).

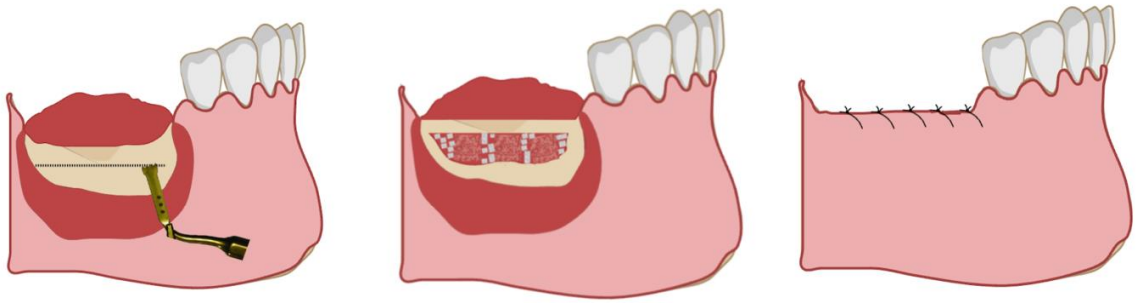


Fig. 1. *The bone segment was moved superiorly after all bone cuts were completed with a piezosurgery device. Two blocks of collagenated equine bone were interposed between the basal bone and the mobilized fragment.*

DISCUSSION

In this technical note, we describe the treatment of posterior mandibular atrophy with interpositional sandwich osteotomy bone grafts without using the mini-screws and miniplates.

The inlay technique, recently revisited (17), facilitates implant placement by raising the bone above the nerve and reducing the interocclusal distance and the crown-implant ratio. Many clinical complications are reported after and during bone grafting, such as fracture of the cortical bone, membrane exposure, bone resorption, and neurological impairment (18).

The absence of micromovement and the blood supply are key factors for successfully integrating the grafted biomaterials and substituting new bone (8). Two research groups reported a high success rate of the inlay graft technique for treating posterior mandible atrophy (19, 20). In these case reports, the effectiveness was shown by a post-operative course without any adverse event, accompanied by a high level of graft integration reported in the radiographical follow-up. The piezosurgery device simplified the technique and reduced the incidence of complications (21, 22).

Many researchers have already used interpositional inlay bone grafting using a fixation device. On the contrary, a few authors have used the technique without using a fixation device. It has the advantage of decreased risk of failure and complication for fracture or bone resorption related to the application of mini-screws and miniplates. In conclusion, the present technique showed that equine collagenated blocks presented higher stability, allowed the elimination of the use of mini-screws and miniplates, and simplified the sandwich technique.

REFERENCES

1. Inchingolo F, Paracchini L, DE Angelis F, Cielo A, Orefici A, Spitaleri D, et al. Biomechanical behavior of a jawbone loaded with a prosthetic system supported by monophasic and biphasic implants. *Oral Implantol* 2016;9(Suppl 1/2016 to N 4/2016):65–70.
2. Stellingsma C, Raghoebar GM, Meijer HJ, Batenburg RH. Reconstruction of the extremely resorbed mandible with interposed bone grafts and placement of endosseous implants. A preliminary report on the outcome of treatment and patients' satisfaction. *Br J Oral Maxillofac Surg*. 1998;36(4):290–5.
3. Moloney F, Stoelinga PJ, Tideman H, de Koomen HA. Recent developments in interpositional bone-grafting of the atrophic mandible. *J Maxillofac Surg*. 1985;13(1):14–23.
4. Lew D, Clark RJ, Jimenez F. Autogenous rib graft-hydroxylapatite augmentation of the severely atrophic mandible: preliminary report. *J Oral Maxillofac Surg*. 1986;44(8):606–8.
5. van der Meij EH, Blankestijn J, Berns RM, Bun RJ, Jovanovic A, Onland JM, et al. The combined use of two endosteal implants and iliac crest onlay grafts in the severely atrophic mandible by a modified surgical approach. *Int J Oral Maxillofac Surg*. 2005;34(2):152–7.
6. Chiapasco M, Zaniboni M, Rimondini L. Autogenous onlay bone grafts vs. alveolar distraction osteogenesis for the correction of vertically deficient edentulous ridges: a 2-4-year prospective study on humans. *Clin Oral Implants Res*. 2007;18(4):432–40.
7. Checchi V, Mazzoni A, Zucchelli G, Breschi L, Felice P. Reconstruction of Atrophied Posterior Mandible with an Inlay Technique and Allograft Block: Technical Description and Histologic Case Reports. *Int J Periodontics Restorative Dent*. 2017;37(6):863–70.
8. Dahlin C, Lekholm U, Linde A. Membrane-induced bone augmentation at titanium implants. A report on ten fixtures followed from 1 to 3 years after loading. *Int J Periodontics Restorative Dent*. 1991;11(4):273–81.
9. Rocchietta I, Simion M, Hoffmann M, Trisciuoglio D, Benigni M, Dahlin C. Vertical Bone Augmentation with an Autogenous Block or Particles in Combination with Guided Bone Regeneration: A Clinical and Histological Preliminary Study in Humans. *Clin Implant Dent Relat Res*. 2016;18(1):19–29.
10. Simion M, Jovanovic SA, Trisi P, Scarano A, Piattelli A. Vertical ridge augmentation around dental implants using a membrane technique and autogenous bone or allografts in humans. *Int J Periodontics Restorative Dent.* 1998;18(1):8–23.
11. Tinti C, Parma-Benfenati S. Vertical ridge augmentation: surgical protocol and retrospective evaluation of 48 consecutively inserted implants. *Int J Periodontics Restorative Dent*. 1998;18(5):434–43.
12. Roccuzzo M, Ramieri G, Bunino M, Berrone S. Autogenous bone graft alone or associated with titanium mesh for vertical alveolar ridge augmentation: a controlled clinical trial. *Clin Oral Implants Res.* 2007;18(3):286–94.
13. Degidi M, Scarano A, Piattelli A. Regeneration of the alveolar crest using titanium micromesh with autologous bone and a resorbable membrane. *J Oral Implantol.* 2003;29(2):86–90.
14. Schettler D. [Sandwich technic with cartilage transplant for raising the alveolar process in the lower jaw]. *Fortschr Kiefer Gesichtschir*. 1976;20:61–3.
15. Stoelinga PJ. [Augmentation of the atrophic mandible using a modified sandwich technic]. *Acta Stomatol Belg.* 1979;76(4):353–4.
16. Misch CM, Misch CE. The repair of localized severe ridge defects for implant placement using mandibular bone grafts. *Implant Dent*. 1995;4(4):261–7.
17. Scarano A, Carinci F, Assenza B, Piattelli M, Murmura G, Piattelli A. Vertical ridge augmentation of atrophic posterior mandible using an inlay technique with a xenograft without miniscrews and miniplates: case series. *Clin Oral Implants Res.* 2011;22(10):1125–30.
18. Buser D, Dula K, Lang NP, Nyman S. Long-term stability of osseointegrated implants in bone regenerated with the membrane technique. 5-year results of a prospective study with 12 implants. *Clin Oral Implants Res.* 1996;7(2):175–83.
19. Barone A, Toti P, Menchini-Fabris GB, Felice P, Marchionni S, Covani U. Early volumetric changes after vertical augmentation of the atrophic posterior mandible with interpositional block graft versus onlay bone graft: A retrospective radiological study. *J Craniomaxillofac Surg.* 2017;45(9):1438–47.
20. Felice P, Barausse C, Barone A, Zucchelli G, Piattelli M, Pistilli R, et al. Interpositional Augmentation Technique in the Treatment of Posterior Mandibular Atrophies: A Retrospective Study Comparing 129 Autogenous and Heterologous Bone Blocks with 2 to 7 Years Follow-Up. *Int J Periodontics Restorative Dent.* 2017;37(4):469–80.
21. Vercellotti T, Stacchi C, Russo C, Rebaudi A, Vincenzi G, Pratella U, et al. Ultrasonic implant site preparation using piezosurgery: a multicenter case series study analyzing 3,579 implants with a 1- to 3-year follow-up. *Int J Periodontics Restorative Dent.* 2014;34(1):11–8.

22. Mavriqi L, Mortellaro C, Scarano A. Inferior Alveolar Nerve Mobilization Using Ultrasonic Surgery With Crestal Approach Technique, Followed by Immediate Implant Insertion: Evaluation of Neurosensory Disturbance. *J Craniofac Surg.* 2016;27(5):1209–11.