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Prof Marincola et al discuss short implants

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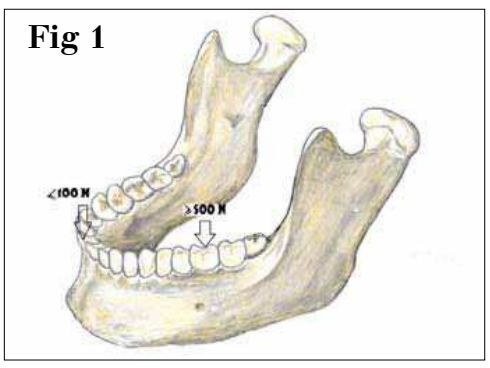
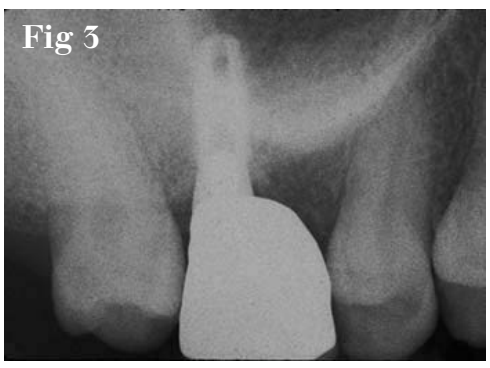
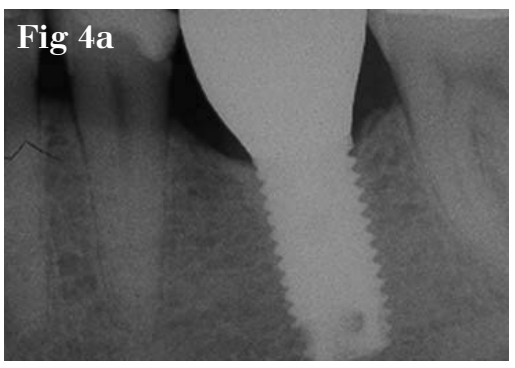
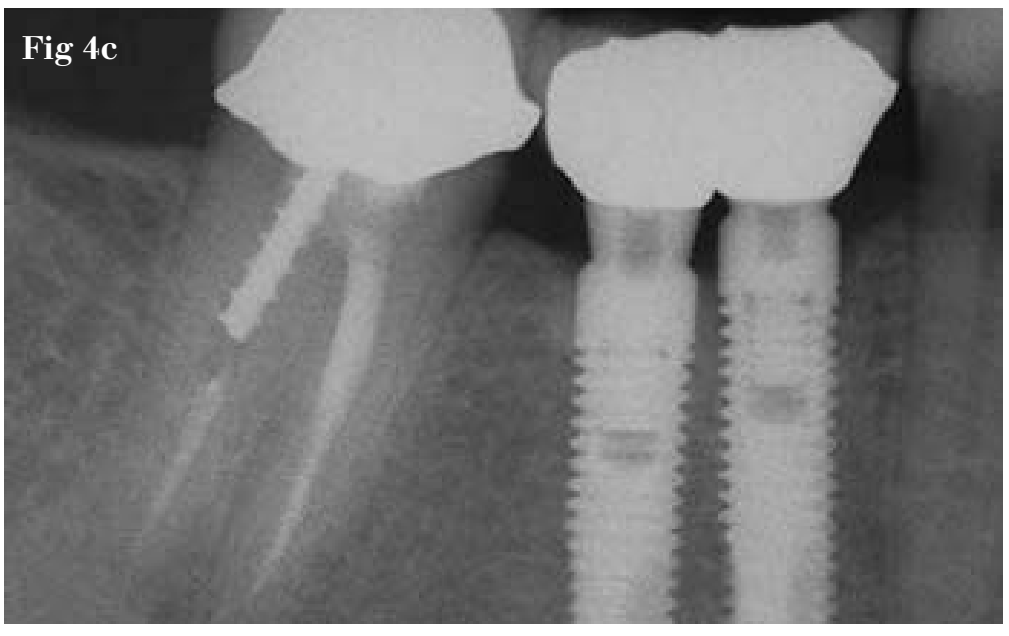
Single molar restoration — Wide implant versus two conventional

Prof Amr Abdel Azim, Dr Amani M Zaki & Dr Mohamed I El-Anwar









The single-tooth restoration has become one of the most widely used procedures in implant dentistry.[1] In the posterior region of the oral cavity, bone volume and density are often compromised. Occlusal forces are greater in this region and, with or without parafunctional habits, can easily compromise the stability of the restorations (Fig. 1). [2, 3]

The single-molar implant-supported restoration has historically presented a challenge in terms of form and function. The mesiodistal dimensions of a molar exceed that of most standard implants (3.75 to 4.0 mm), creating the possibility of functional overload resulting in the failure of the retaining components or the failure of the implant (Figs. 2 & 3).[4] Wider-diameter implants have a genuine use in smaller molar spaces (8.0 to 11.0mm) with a crestal width greater than or equal to 8mm (Fig. 4 a).[5] Clinical parameters governing the proposed restoration should be carefully assessed in light of the availability of implants and components that provide a myriad of options in diameter, platform configurations and prosthetic connections. Many of the newer systems for these restorations are showing promising results in recent clinical trials.[6-8] It has further been suggested by Davarpanah and others,[9] Balshi and others,[2] English and others[10] and Bahat and Handelsman[11] that the use of multiple implants may be the ideal solution for single-molar implant restorations (Figs. 4 b & c).

Most standard implants and their associated prosthetic components, when used to support a double implant molar restoration, will not fit in the space occupied by a molar unless the space has been enlarged (12mm or larger).[4] Moscovitch suggests that the concept of using 2 implants requires the availability of a strong and stable implant having a minimum diameter of 3.[5] mm. Additionally, the associated prosthetic components should ideally not exceed this dimension.[2]

Finite element analysis (FEA) is an engineering method that allows investigators to assess stresses and strains within a solid body.10-13 FEA provides calculation of stresses and deformations of each element alone and the net of all elements. A finite element model is constructed by breaking a solid object into a number of discrete elements that are connected at common nodal points. Each element is assigned appropriate material properties that correspond to the properties of the structure to be modelled. Boundary conditions are applied to the model to stimulate interactions with the environment.[14] This model allows simulated force application to specific points in the system, and it provides the resultant forces in the surrounding structures. FEA is particularly useful in the evaluation of dental prostheses supported by implants.[15-16] Two models were subjected to FEA study

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to compare between a wide implant restoration versus the two implant restoration of lower first molar.

Material and Methods

Three different parts were modelled to simulate the studied cases; the jaw bones, implant/abutment assembly, and crown. Two of these parts (jaw bone and implant/abutment) were drawn in three dimensions by commercial general purpose CAD/CAM software "AutoDesk Inventor" version 8.0. These parts are regular, symmetric, and its dimensions can be simply measured with their full details.

Fig 5

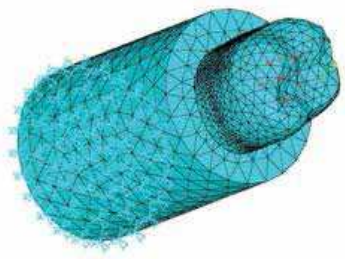
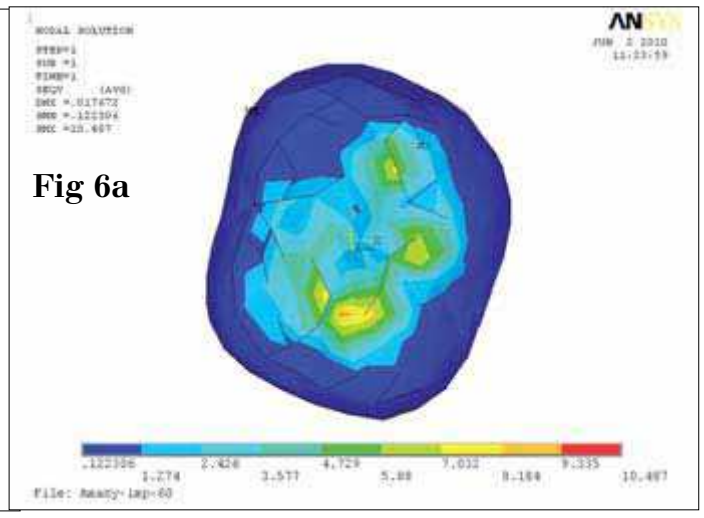


Fig 6a



On the other hand, crown is too complicated in its geometry therefore it was not possible to draw it in three dimensions with sufficient accuracy. Crown was modelled by using three-dimensional scanner, Roland MDX-15, to produce cloud of points or triangulations to be trimmed before using in any other application.

The second phase of difficulty might appear for solving the engineering problem, is importing and manipulating three parts one scanned and two modelled or drawn parts on a commercial FE package. Most of CAD/CAM and graphics packages deal with parts as shells (outer surface only). On the other hand the stress analysis required in this study is based on volume of different materials.[3] Therefore set of operations like cutting volumes by the imported set of surfaces in addition to adding and subtracting volumes can ensure obtaining three volumes representing the jaw bone, implant/abutment assembly, and crown.[2] Bone was simulated as cylinder that consists of two parts. The inner part represents the spongy bone (diameter 14mm and height 22mm) that filling the internal space of the other part (shell of 1mm thickness) that represents cortical bone (diameter 16mm and height 24mm). Two implants were modelled one of 3.7mm diameter and the other of 6.0mm. The implants/abutment design and geometry were taken from Zimmer dental catalogue (Fig. 5).

'On the other hand the stress analysis required in this study is based on volume of different materials'

Linear static analysis was performed. The solid modelling and finite element analysis were performed on a personal computer Intel Pentium IV, processor 2.8 GHz, 1.0 GB RAM. The meshing software was ANSYS version 9.0 and the used element in meshing all three dimensional model is eight nodes Brick element (SOLID45), which has three degrees of freedom (translations in the global directions). Listing of the used materials in this analysis is found in Table 1. The two models

were subjected to 120 N vertical load equally distributed (20 N on six points simulate the occlusion; one on each cusp and one in the central fossa). On the other hand, the base of the cortical bone cylinder was fixed in all directions as a boundary condition.[17-21]

Results and Discussion

Results of FEA showed a lot of details about stresses and deformations in all parts of the two models under the scope of this study. Figures 6a & b showed a graphical comparison between the crowns of the two models which are safe under this range of stresses (porcelain coating, gold crown, and implants showed the same ranges of safety). No critical difference can be noticed on these parts of the system. All differences might be found are due to differences in supporting points and each part volume to absorb load energy (equation 2).**

Generally a crown placed on two implants is weaker than the same crown placed on one implant. This fact is directly reflected on porcelain coating and the two implants that have more deflections. Comparing wide implant model with the two implants from the geometrical point of view it is simply noted that cross sectional area was reduced by 43.3 per cent while the side area increased by 6.5 per cent. Using one implant results as a reference in a detailed comparison between the two models by using equation (1) resulted in Table 2 for porcelain coating, gold crown, implant(s), spongy and cortical bones respectively.

Difference % = {One implant Result—Two implants Result}*100 / One implant Result…(1)

Spongy bone deformation and stresses (Table 2) seems to be the same in the two cases. Simple and fast conclusion can be taken that using one wide implant is equivalent to using two conventional implants. On the other hand a very important conclusion can be exerted that, under axial loading, about 10 per cent increase in implant side area can overcome reduction of implant cross section area by 50 per cent. In other words, effectiveness of increasing implant side area might be five times higher than the increasing of implant cross section area on spongy bone stress level under axial loading. Starting from Figures 7 a & b, slight differences can be noticed on spongy bone between the two models results. The stresses on the spongy bone are less by about five per cent in the two implants model than the one wide diameter implant.

The exceptions are the relatively increase in maximum compressive stresses and deformations of order 12 per cent and 0.3 per cent respectively.

The bone is known to respond the best to compressive and the least to shear stresses[22], so considering the difference in compressive stresses less significant, the two implants were found to have a better effect on spongy bone. Contrarily, Figures 8a & b, showed better performance with cortical bone in case of using one wide implant over using two implants, that, deformations in cortical bone are less by 20 per cent while the stresses are less by about 40 per cent. The stresses and displacements were significantly higher in the two implant model due to having two close holes, which results in weak area in-between.

Material	Poisson's ratio	Young's modulus MPa
Coating (porcelain)	0.3	67,200
Restoration (gold)	0.3	96,000
Implants (titanium)	0.35	110,000
Spongy bone	0.3	150
Cortical bone	0.26	1,500

Table 1

Conclusions

This study showed various results between cortical and spongy bone. It was expected that the maximum stresses in the cortical bone was placed in the weak area between the two implants. In addition to be higher than the case of using one wide implant. Although the middle part of spongy bone was stressed to the same level in the two cases, using two implants resulted in more volume of the spongy bone absorbed

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the load energy** which led to reduction of stress concentration and rate of stress deterioration by moving away from implants. That is considered better distribution of stresses from the mechanics point of view, which may result in longer lifetime. Porcelain coating showed less stress in case of two implants, longer life for the brittle coating material is expected.

Contrarily more stresses were found on the gold crown placed on two implants due to its volume reduction (less material under the same load). This is clearly seen in increasing stresses on the two implants, that more load effect was transferred through the weak crown to the two implants. That showed maximum stresses in the area under the crown, while the wide implant showed maximum stresses at its tip. Looking to energy** absorption and stress concentration on whole system starting from coating to cortical and spongy bone, although the stress levels found was too low and far from cracking danger, the following conclusions can be pointed out; the total results favour the two implants in spongy bone and the wide implant in the cortical layer, but the alveolar bone consists of spongy bone surrounded by a layer of cortical bone. It's also well known that according to the degree of bone density the alveolar bone is classified to D1,2,3,4 23 in a descending order.

So, provided that the edentulous space after the molar extraction permits, it's recommended in the harder bone quality (D1,2) to use one wide diameter implant and in the softer bone (D3,4) quality two average sized implants. Therefore more detailed study to compromise between the two implants size/design and intermediate space can put this stress values in safe, acceptable, and controllable region under higher levels of loading.

**The area under the __-__ curve up to a given value of strain is the total mechanical energy per unit volume consumed *Table 1* by the material in straining it to that value (Fig. 9). This is easily shown as follows in equation [2]:

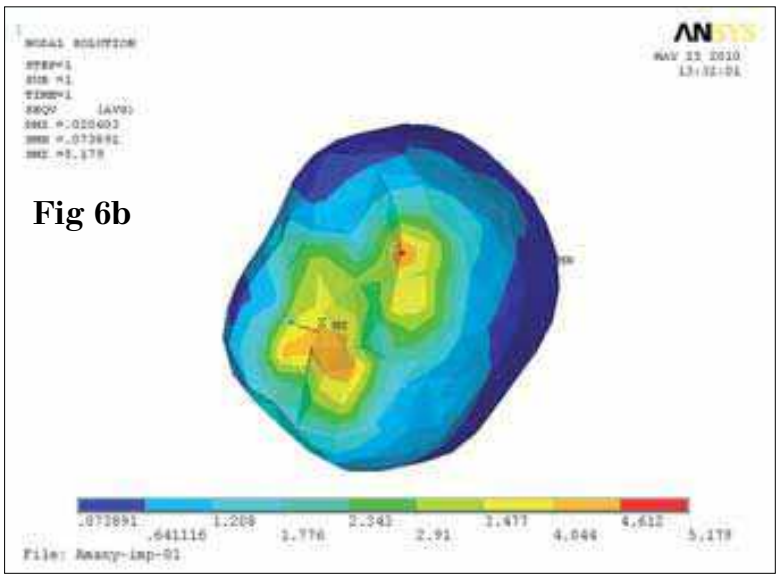

Fig 6b

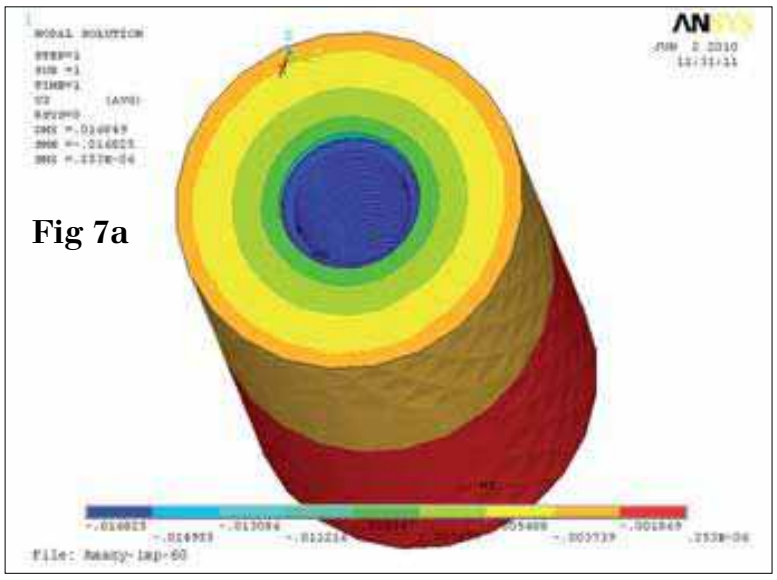

Fig 7a

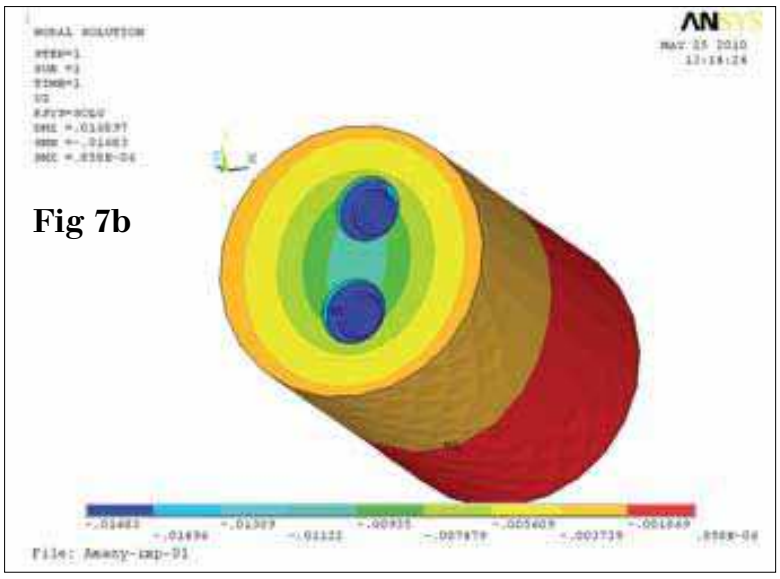

Fig 7b

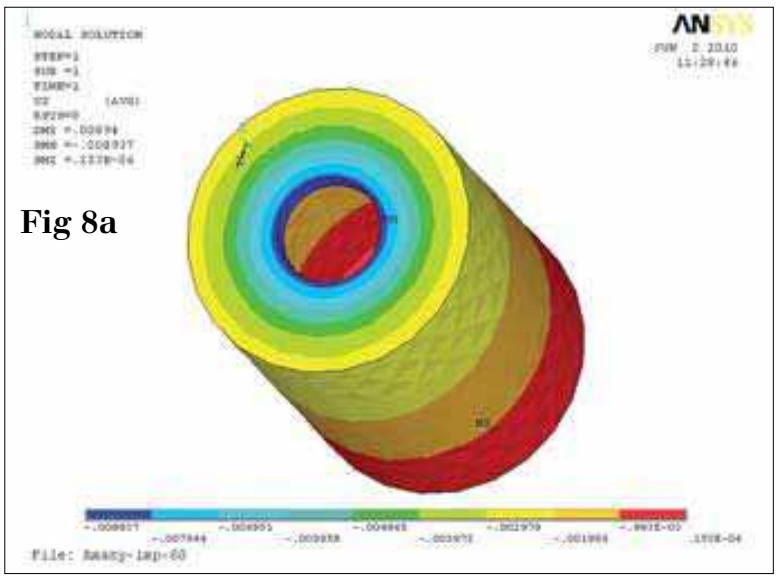

Fig 8a

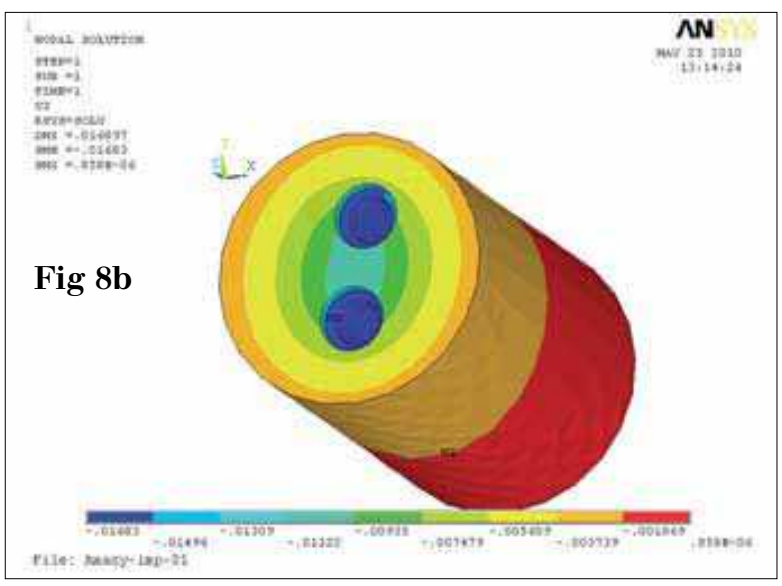

Fig 8b

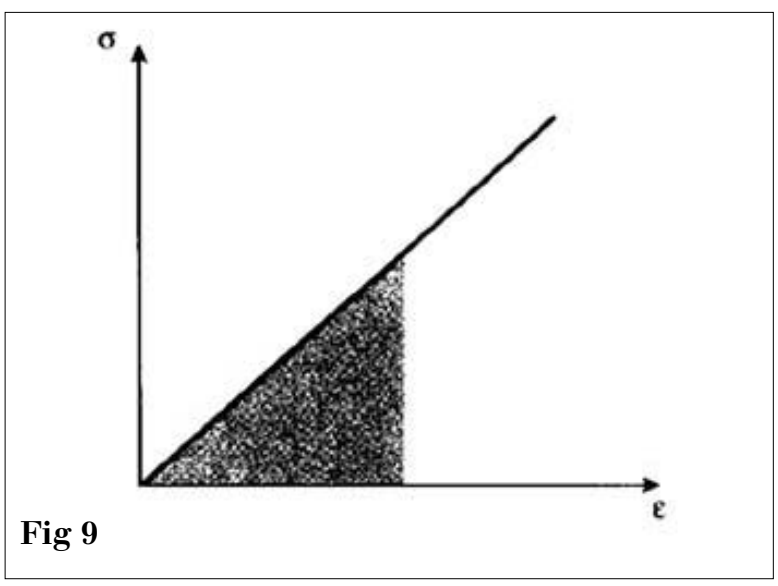

Fig 9

$$U^* = \frac{1}{V}\int P\,dL = \int_0^L \frac{P}{A_0}\frac{dL}{L_0} = \int_0^\epsilon \sigma\,d\epsilon$$

Fig 10

Differences %	Porcelain coating (1mm)	Gold crown	Implants	Spongy bone	Cortical bone
U_{sum}	-17.86	-16.70	-8.18	-0.28	-19.57
U_z	-11.10	-11.10	-2.72	-0.03	-19.62
S_1	31.59	-179.99	-6.72	5.96	-37.17
S_3	0.71	-33.44	-310.74	-11.24	-70.43
S_{int}	-1.26	-18.08	-166.39	4.75	-31.82
S_{eqv}	0.25	-10.22	-196.86	4.00	-39.17

Table 2

Summary

Restoration of single molar using implants encounters many problems; mesio-distal cantilever due to very wide occlusal table is the most prominent. An increased occlusal force posteriorly worsens the problem and increases failures. To overcome the overload, the use of wide diameter implants or two regular sized implants were suggested. The aim of this study was to verify the best solution that has the best effect on alveolar bone under distributed vertical loading. Therefore, a virtual experiment using Finite Element Analysis was done using ANSYS version 9. A simplified simulation of spongy and cortical bones of the jaw as two co-axial cylinders was utilised. Full detailed with high accuracy simulation for implant, crown, and coating was implemented. The comparison included different types of stresses and deformations of both wide implant and two regular implants under the same boundary conditions and load application.

The three main stresses compressive, tensile, shear and the equivalent stresses in addition to the vertical deformity and the total deformities were considered in the comparison between the two models. The results were obtained as percentages using the wide implant as a reference. The spongy bone showed about five per cent less stresses in the two implants model than the one wide diameter implant. The exceptions are the relatively increase in maximum compressive stresses and deformations of order 12 per cent and 0.3 per cent respectively.

The stresses and displacements on the cortical bone are higher in the two implant model due to having two close holes, which results in weak area in-between. The spongy bone response to the two implants was found to be better considering the stress distribution (energy absorbed by spongy bone**). Therefore, it was concluded that, using the wide diameter implant or two average ones as a solution depends on the case primarily. Provided that the available bone width is sufficient mesio distally and buccolingualy, the choice will depend on the type of bone. The harder D1,2 types having harder bone quality and thicker cortical plates are more convenient to the wide implant choice. The D3,4 types consist of more spongy and less cortical bone, are more suitable to the two implant solution. DT

Editorial note: A complete list of references is available from the author.

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Time proven clinical success of the SHORT™ implant

Prof Dr Mauro Marincola, MDS Angelo Paolo Perpetuini, Dr Stefano Carelli, Prof G. Lombardo & Dr Vincent Morgan

In 1892, Julius Wolff, a German surgeon, published his seminal observation that bone changes its external shape and internal, cancellous architecture in response to stresses acting on it (Wolff's law of bone modelling and remodelling). Therefore, it is a significant engineering challenge to design a short implant that biocompatibly transfers occlusal forces from its prosthetic restoration to the surrounding bone. It requires the understanding and application of many basic biological, mechanical, and metallurgical principles. It is paramount that the entire design of a SHORT™ implant optimises the effectiveness of each of its features within the implant's available surface area and length. Clinical success cannot be met by any single implant design feature such as surface area, but rather requires the appropriate integration of all of its features.

Since an implant's design dictates its clinical and mechanical capabilities, it is scientifically approved that bone healing around a plateau-designed implant is different than the appositional bone (the bone that is formed by osteoblasts after cell mediated interfacial remodelling) around threaded implants. The plateaued, tapered and root-formed implant body provides for 30 per cent more surface area than comparably-sized threaded implants. But more importantly, the plateaus provide for an intramembranous-like and faster bone formation (20–50 microns per day), resulting in a unique Haversian bone with clinical capabilities different from the slower forming (1–3 microns per day) of appositional bone around threaded implants.[1,2] Additionally, the plateaus provide for the transfer of compressive forces to the bone throughout the entire implant.[3,4]

'Therefore, it is a significant engineering challenge to design a short implant that biocompatibly transfers occlusal forces from its prosthetic restoration to the surrounding bone'

Description

We analysed the most time-

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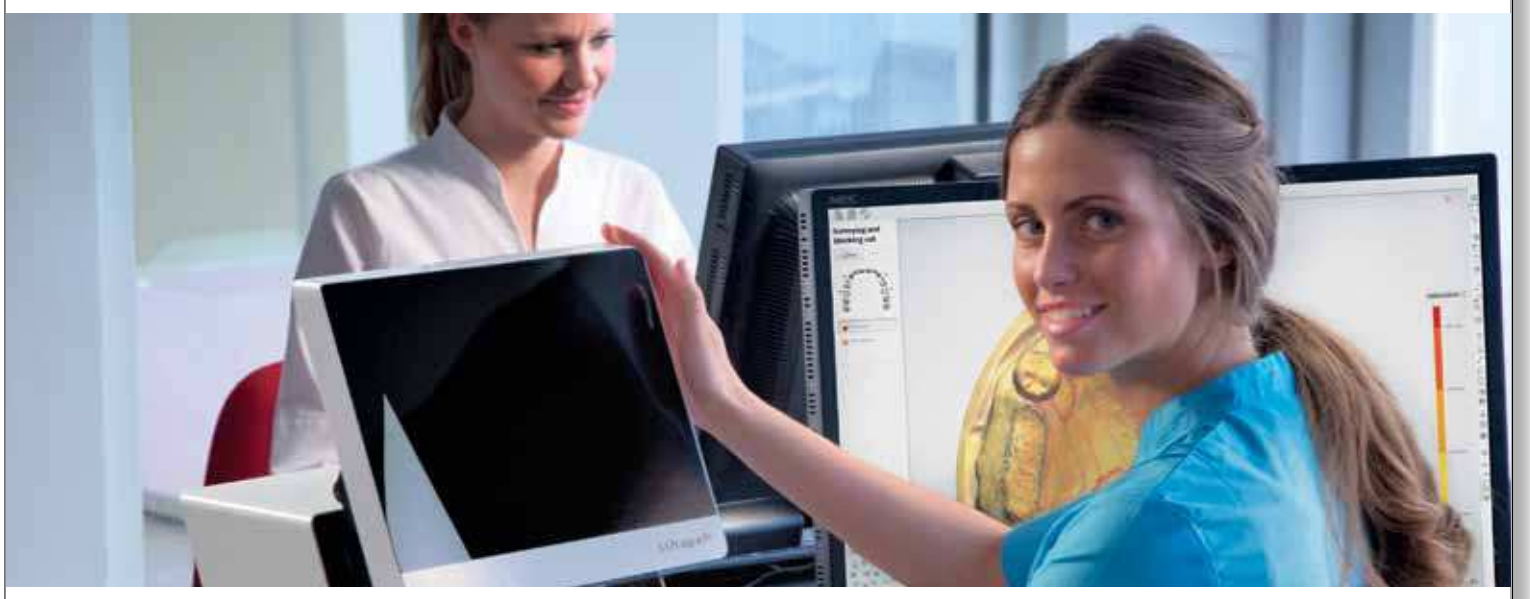

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proven short implant on the market that was called the Driskol Precision Implant in the early 1980s, than Stryker and the Bicon Dental Implant from 1993 (Boston, USA).

The Bicon implant has a bacterially-sealed 1.5° locking taper (galling or cold welding) connection[5,6] between the abutment and implant, with the ability for 360° of universal abutment positioning. Having a bacterially-sealed connection eliminates the bacterial flux associated with clinical odours and tastes and reduces inflammation and bone loss consistently.

Another unique characteristic is the sloping shoulder that facilitates the appropriate transfer of occlusal loads to the bone when positioned below the bony crest. But more practically, the sloping shoulder facilitates aesthetic implant restorations, for it provides space for the interdental papillae with bony support even when an implant is contiguous to another implant or tooth. The sloping shoulder design has been, since 1985, the basis of a sensible biological width and the origin of platform switching.

The 360° of universal abutment positioning provides for the extra-oral cementation of

'The single-tooth implant is a viable alternative for single tooth replacement'

crowns; the use of the cementless and screwless Integrated Abutment Crown (IAC™)[7], the intraoral bonding of fixed bridges, which eliminates the need for cutting, indexing and soldering of bridge frameworks, multiple and easy removal of abutments over time; and the slight aesthetic rotational adjustments during and prior to the seating of a restoration.

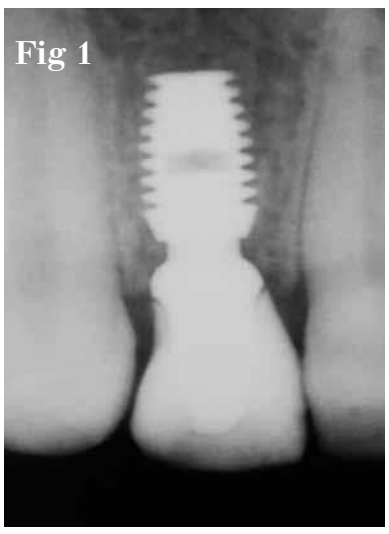
Clinical long-term results

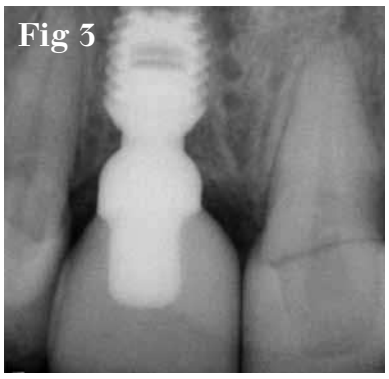
In the following long-term case description we can observe the stability of the crestal bone around the sloping shoulder of the plateau implant. Clinically, the soft tissue contour around the Integrated Abutment Crowns indicates a healthy and stable epithelial tissue.

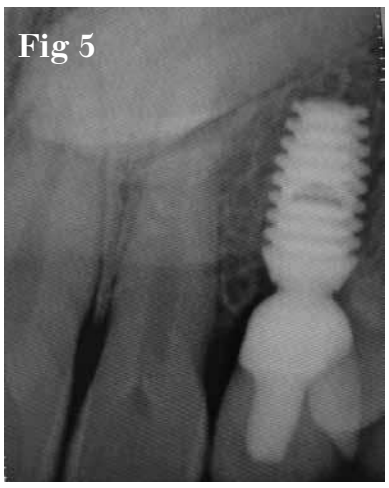
The single-tooth implant is a viable alternative for single tooth replacement.[8] Single-tooth replacement with endosseous implants has shown satisfactory clinical performance in different jaw locations.

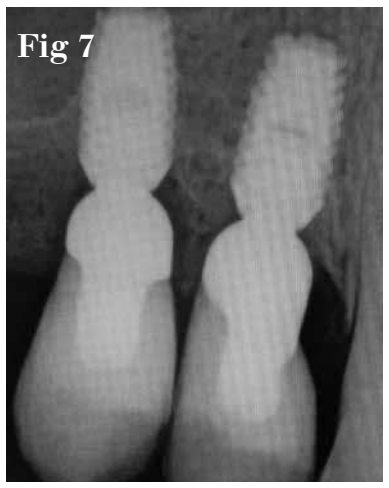
Minimal or no crestal bone resorption is considered to be an indicator of the long-term success of implant restorations. Mean crestal bone loss ranging from 0.12-0.20mm has been reported one year after the insertion of single-tooth implant restorations.[9] After the first year, an additional 0.01mm to 0.11mm of annual crestal bone loss has been reported on single-tooth implant restorations. Some implants demonstrate no crestal bone loss and/or crestal bone gain after insertion of definitive restorations.[10]

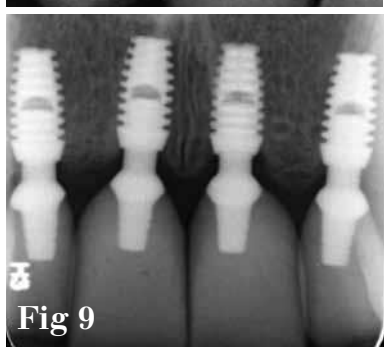
Crestal bone gain has been documented on immediate and early loaded implants with a chemically modified surface after one year of follow up.[11] A six-year prospective study reported that 43.8 per cent of splinted Morse taper implants experienced some bone gain.[12] Crestal bone gain has been documented around immediately loaded Bicon implants.[13] The factors that lead to peri-implant bone gain in different

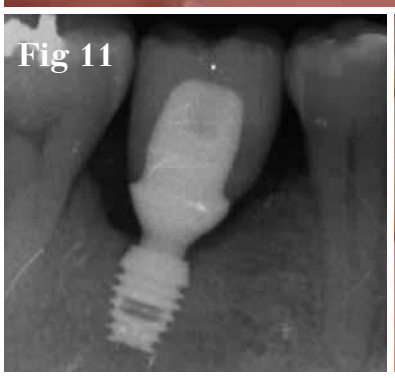


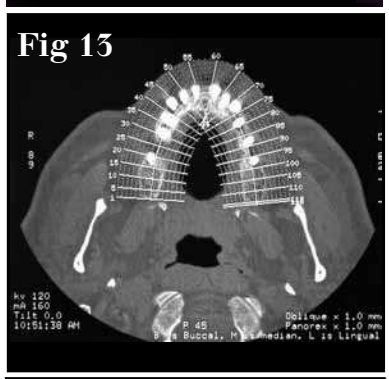


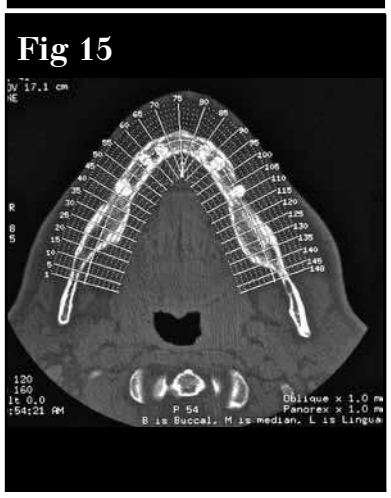












implant designs have not been investigated. It would be beneficial for the dental practitioner to understand what factors are associated with crestal bone gain on single-tooth implants after crown insertion. Radiographic long-term control also as a clinical observation of the soft tissue structures surrounding the abutment emergence profile can provide the clinician with a better understanding of an implant's bone/soft tissue stability (Figs 1–12).

The ideal scenario in modern implant dentistry would be the implant replacement for every missing single tooth (Figs 13&14). The single tooth replacement guarantees good aesthetics, consequently to the fact that a single crown that follows all criteria of a natural-looking soft tissue emergence profile can support the soft tissue in order to recreate papillae anatomy.

Another important aspect of single crown restorations on implants is that the patient can follow a better oral hygiene compared to bridgeworks. Nevertheless, bridgeworks are commonly used as alternatives to single tooth replacement. The

'The ideal scenario in modern implant dentistry would be the implant replacement for every missing single to'

reasons are multifactorial, with the cost benefit factor at first place (Figs 15&16). Another significant facet is the atrophic bone situation of the patient, were complicated and expensive bone graft procedures are needed before even thinking of placing single implants.

Alternatively to sophisticated and expensive bridge works (Figs 17&18), cost-effective and simple prosthetic techniques were developed in the last years. One of these techniques, the Fixed on SHORT™, allows to provide the patients with bone atrophies or partial bone deficiencies with a fixed, metal free prosthetic that can be supported by four to six short implants (Figs 19–22).

Conclusion

In this short and synthetic article, the authors like to show the variety of treatment options when implants and prosthetic materials are used with the criteria of long-term crestal bone preservation, recreation and long-term stabilisation of the biological width around the implant/crown and the use of short- and ultra-short implants in all clinical situations. The proper selection of an ultra-short or short implant depends strictly on the implant design, which dictates the implant's function. DT

Figs
Figs. 1–12_Radiographic long-term control helps maintain the implant's bone/soft tissue stability.
Figs. 13–16_Bridge works.
Figs. 17 & 18_Complex bridge works.
Figs. 19–22_Fixed-on-SHORTTM technique for fixed, metal free prosthetics.

Editorial note: A complete list of references is available from the publisher.

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Stem cells in implant dentistry

Dr André Antonio Pelegrine

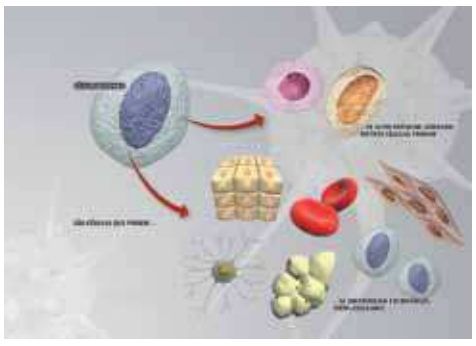

Fig. 1 A stem cell following either self-replication or a differentiation pathway.

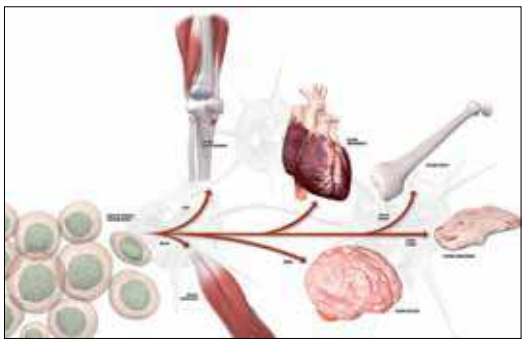

Fig. 2 Different tissues originated from mesenchymal stem cells.

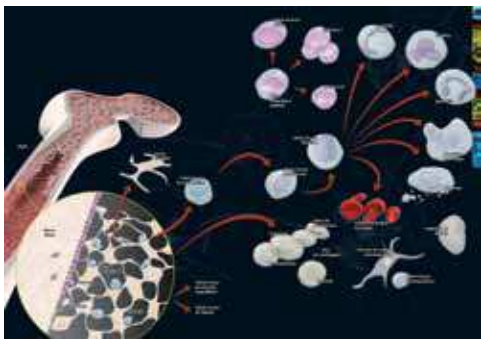

Fig. 3 The diversity of cell types present in the bone marrow.

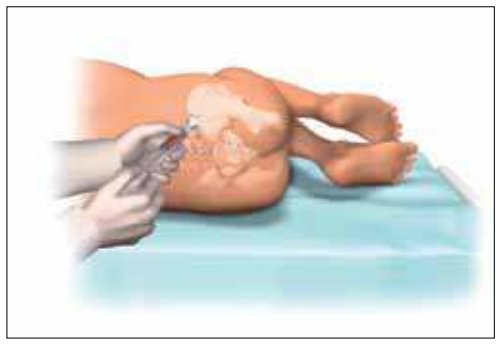

Fig. 4a Point of needle puncture for access to the bone marrow space in the iliac bone.

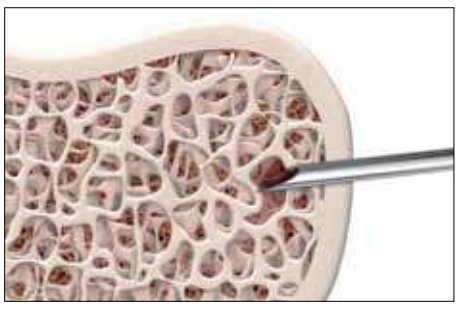

Fig. 4b The needle inside the bone marrow.

Fig. 5a A bone graft being harvested from the chin (mentum).

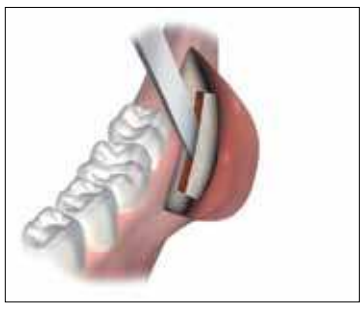

Fig. 5b A bone graft being harvested from the angle of the mandible (ramus).

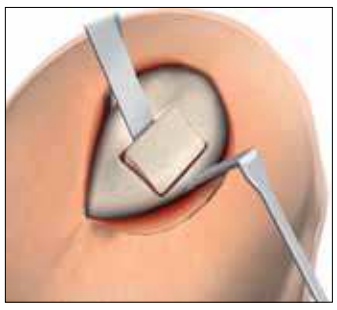

Fig. 5c A bone graft being harvested from the angle of the skull (calvaria).

Fig. 5d_A bone graft being harvested from the angle of the leg (tibia or fibula).

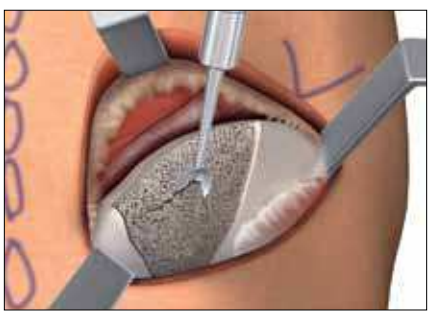

Fig. 5e_A bone graft from the pelvic bone (iliac).

Fig. 6 A critical bony defect created in the skull (calvaria) of a rabbit.

Fig. 7 A primary culture of adult mesenchymal stem cells from the bone marrow after 21 days of culture.

Fig. 8a A CT image of a rabbit's skull after bone-sparing grafting without stem cells (blue arrow). Note that the bony defect remains.

Fig. 8b A CT image of a rabbit's skull after bone-sparing grafting with stem cells. Note that the bony defect has almost been resolved.

Fig. 9 A bone block from a musculoskeletal tissue bank.

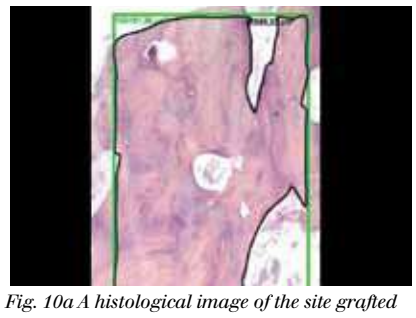

Fig. 10a A histological image of the site grafted with bank bone combined with bone marrow. Note the presence of considerable amounts of mineralised tissue.

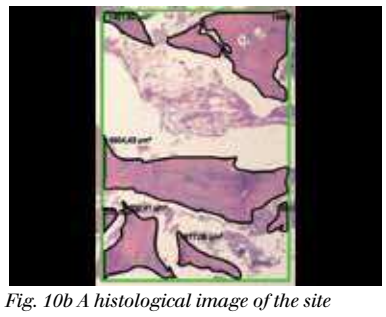

Fig. 10b A histological image of the site grafted with bank bone not combined with bone marrow. Note the presence of low amounts of mineralised tissue.

Fig. 11a_Bone marrow.

Fig. 11b_Bone marrow transfer into a conic tube in a sterile environment (laminar flow).

Fig. 11c_Bone marrow homogenisation in a buffer solution (laminar flow).

The human body contains over 200 different types of cells, which are organised into tissues and organs that perform all the tasks required to maintain the viability of the system, including reproduction. In healthy adult tissues, the cell population size is the result of a fine balance between cell proliferation, differentiation, and death. Following tissue injury, cell proliferation begins to repair the damage. In order to achieve this, quiescent cells (dormant cells) in the tissue become proliferative, or stem cells are activated and differentiate into the appropriate cell type needed to repair the damaged tissue. Research into stem cells seeks to understand tissue maintenance and repair in adulthood and the derivation of the significant number of cell types from human embryos.

It has long been observed that tissues can differentiate into a wide variety of cells, and in the case of blood, skin and the gastric lining the differentiated cells possess a short half-life and are incapable of renewing themselves. This has led to the idea that some tissues may be maintained by stem cells, which are defined as cells with enormous renewal capacity (self-replication) and the ability to generate daughter cells with the capacity of differentiation. Such cells, also known as adult stem cells, will only produce the appropriate cell lines for the tissues in which they reside (Fig 1).

> *'Research into stem cells seeks to understand tissue maintenance and repair in adulthood and the derivation of the significant number of cell types from human embryos'*

Not only can stem cells be isolated from both adult and embryo tissues; they can also be kept in cultures as undifferentiated cells. Embryo stem cells have the ability to produce all the differentiated cells of an adult. Their potential can therefore be extended beyond the conventional mesodermal lineage to include differentiation into liver, kidney, muscle, skin, cardiac, and nerve cells (Fig 2).

The recognition of stem cell potential unearthed a new age in medicine: the age of regenerative medicine. It has made it possible to consider the regeneration of damaged tissue or an organ that would otherwise be lost. Because the use of embryo stem cells raises ethical issues for obvious reasons, most scientific studies focus on the applications of adult stem cells. Adult stem cells are not considered as versatile as embryo stem cells because they are widely regarded as multipotent, that is, capable of giving rise to certain types of specific cells/tissues only, whereas the embryo stem cells can differentiate into any types of cells/tissues. Advances in scientific research have determined that some tissues have greater difficulty regenerating, such as the nervous tissue, whereas bone and blood, for instance, are considered more suitable for stem cell therapy.

In dentistry, pulp from primary teeth has been thoroughly investigated as a potential source of stem cells with promising results. However, the regeneration of an entire tooth, known as third dentition, is a highly complex process, which despite some promising results with animals remains very far from clinical applicability. The opposite has been observed in the area of jawbone regeneration, where there is a higher level of scientific evidence for its clinical applications. Currently, adult stem cells have been harvested from bone marrow and fat, among other tissues.

Bone marrow is haematopoietic, that is, capable of producing all the blood cells. Since the 1950s, when Nobel Prize winner Dr E Donnall Thomas demonstrated the viability of bone marrow transplants in patients with leukaemia, many lives have been saved using this approach for a variety of immunological and haemat-

Fig. 11d_Bone marrow combined with Ficoll (to aid cell separation).

Fig. 11d_Bone marrow combined with Ficoll (to aid cell separation).

opoietic illnesses. However, the bone marrow contains more than just haematopoietic stem cells (which give rise to red and white blood cells, as well as platelets, for example); it is also home to mesenchymal stem cells (which will become bone, muscle and fat tissues, for instance; Fig 3).

Bone marrow harvesting is carried out under local anaesthesia using an aspiration needle through the iliac (pelvic) bone. Other than requiring a competent doctor to perform such a task, it is not regarded as an excessively invasive or complex procedure. It is also not associated with high levels of discomfort either intra or post-operatively (Figs 4a&b).

'Bone reconstruction is a challenge in dentistry (also in orthopaedics and oncology) because rebuilding bony defects caused by trauma, infections, tumours or dental extractions requires bone grafting'

Bone reconstruction is a challenge in dentistry (also in orthopaedics and oncology) because rebuilding bony defects caused by trauma, infections, tumours or dental extractions requires bone grafting. The lack of bone in the jaws may impede the placement of dental implants, thus adversely affecting patients' quality of life. In order to remedy bone scarcity, a bone graft is conventionally harvested from the chin region or the angle of the mandible. If the amount required is too large, bone from the skull, legs or pelvis may be used. Unlike the process for harvesting bone marrow, the process involved in obtaining larger bone grafts is often associated with high levels of discomfort and, occasionally, inevitable post-operative sequelae (Figs 5a-e).

The problems related to bone grafting have encouraged the use of bone substitutes (synthetic materials and bone from human or bovine donors, for example). However, such materials show inferior results compared with autologous bone grafts (from the patient him/herself), since they lack autologous proteins. Therefore, in critical bony defects, that is, those requiring specific therapy to recover their original contour, a novel concept to avoid autologous grafting, involving the use of bone-sparing material combined with stem cells from the same patient, has been gaining ground as a more modern philosophy of treatment. Consequently, to the detriment of traditional bone grafting (with all its inherent problems), this novel method of combining stem cells with mineralised materials uses a viable graft with cells from the patient him/herself without the need for surgical bone harvesting.

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