CLINICAL IMPLICATIONS OF NANOSURFACE TECHNOLOGY ON CLINICAL SUCCESS AND SURVIVAL RATE OF SINGLE IMPLANT RESTORATIONS: A REVIEW

Gareth Z. Benic1, Andrew Tawse-Smith2 and Vincent Bennani3

ABSTRACT

Background: Surface nanofeatures of commercially available dental implants have been assessed only recently. Preclinical studies demonstrate a substantial improvement on the rate and extent of osseointegration for nanosurface implants compared to their predecessors. However, to our knowledge few human studies have been conducted to report on this recently introduced implant surface.

Aim: To review the clinical success and survival rate of nanosurface single implant restorations by focusing on human studies using the Nanotite dental implant

Materials and Methods: A search of the main electronic databases for articles published in the last 10 years was conducted. The present review focussed on literature involving Biomet3i’s Nanotite implant only, with the intention to investigate other implant companies in the near future. Case reports and review articles were discluded.

Results: Out of 302 studies, two were identified to meet the author’s inclusion criteria. These two studies described a combined survival rate of 95.3% for 142 Nanotite single tooth dental implants, both for immediately loaded scenarios. Nanotite implants seem to be a viable option in implant rehabilitation and perform comparatively well to other immediately loaded implants with various surface enhancements.

Conclusion: Nanosurfaced implants, such as Nanotite, show potential to control the biological activity of the implant surface but additional human studies with longer follow-ups are needed to provide more insight into the long-term clinical outcomes. Standardisation of future implant studies is also necessary.

UNITERMS: Dental implants; Single-tooth implant; Nanotechnology. R Periodontia 2011; 21:55-64.

INTRODUCTION

Osseointegration and implant surface engineering

Osseointegration is defined as the time dependent healing process whereby clinically asymptomatic rigid fixation of alloplastic materials is achieved and maintained in bone during functional loading (Zarb & Albrektsson 1991). Osseointegration was originally observed in implants with titanium surfaces and was considered the consequence of a foreign body response: the surgical trauma due to implantation causes a severe oxidative stress resulting in the overproduction of free radicals and oxygenated derivatives at the titanium surface. This leads to the thickening of the titanium dioxide (TiO2) layer of the surface (Dohan Ehrenfest et al. 2010). Calcium and phosphorus ions from the bone matrix are then incorporated into the TiO2 porous layer making the bone/implant interface highly dynamic (Dohan Ehrenfest et al. 2010). On the other hand, the contamination or destruction of the TiO2 layer results in the pathological loss of osseointegration, called peri-implantitis (Mouhyi et al. 2009).

Characteristics of the bone implant interface have been of particular interest in dental implant research.
Different techniques have been attempted to improve the bone implant interface by modifying implant surfaces with the aim of accelerating bone healing and improving bone anchorage to the implant (Albrektsson & Wennerberg 2004a, Albrektsson & Wennerberg 2004b) (see Table 1).

Typically there have been two different techniques used. In the first technique, the interface is improved chemically by incorporating inorganic phases, such as calcium phosphate, on or into the TiO2 interface layer, which might stimulate bone regeneration and improve the biochemical interlocking between bone matrix proteins and surface materials (Coelho et al. 2009). Incorporation of organic molecules, such as proteins, enzymes or peptides, to induce specific cell and tissue responses is a variant of this first approach and is known as biochemical surface modification (Puleo & Nanci 2009, Morra 2006, Morra 2007, Morra et al. 2009, Bussy et al. 2008, Morra et al. 2006).

In the second technique, the interface is improved physically by surface topography. How these surface structures influence the healing response has until recently been limited to the millimetre (mm) and micrometre (µm) length scales (Svanborg et al. 2009). At the micrometre level, the reasoning for this approach is that a rough surface presents a higher developed area than a smooth surface, and thus increases bone anchorage and reinforces the biomechanical interlocking of the bone with the implant, at least up to a certain level of roughness (Coelho et al. 2009). Surface nanostructures of commercially available dental implants have been assessed only recently (Svanborg et al. 2009).

What is Nanotopography?

Nanotechnology has been defined as ‘the creation of functional materials, devices and systems through control of matter on the nanometer length scale (1–100 nm), and exploitation of novel phenomena and properties (physical, chemical, and biological) at that length scale’ (National Aeronautics and Space Administration). Nanotechnology involves materials that have a nanosized topography or are composed of nanosized structures (Junker et al. 2009). All surfaces show nanotopography, but not all of them have significant nanosized structures (Dohan Ehrenfest et al. 2010). When describing nanostructures, it is essential to differentiate between the number of nanoscale dimensions: smooth, rough (one dimension), patterned/porous/tubes (two dimensions), particle (three dimensions) (Dohan Ehrenfest et al. 2010). Nanotextured surfaces have one dimension at the nanoscale (peak height), which can also appear in repetitive and homogeneous forms as nanoroughness or nanorugosity (Bucci-Sabbattini et al. 2010). Nanopatterns have two nanoscale dimensions so the dimensions of the repetitive pattern are nanometric. Nanoparticles have three nanoscale dimensions so each of their three spatial dimensions are also in the nanometre range (Dohan Ehrenfest et al. 2010).

Repetitiveness and homogeneity are key parameters to define the nanostructure of an implant surface, but these are difficult to quantify and are considered qualitative morphological parameters (Dohan Ehrenfest et al. 2010). If nanostructures are not clearly visible (no patterns, no particles, insignificant texture) or not homogeneous and repetitive, the surface is considered as nanosmooth (Dohan Ehrenfest et al. 2010).

At the nanometre level, the effects on the biological response are almost entirely unknown for commercially available implants (Wennerberg & Albrektsson 2010). Nanostructures of the most common commercially available dental implants have been assessed just recently (Svanborg et al. 2009). A handful of experimental studies have shown that a change in the nanotopography of an implant surface has a significant impact on the behaviour of bone cells (Mendonça et al. 2009, Vetrone et al. 2009, Dalby et al. 2006). It is thought that a more textured (rough) surface topography increases the surface energy. A high surface energy increases its wettability to blood and increases the spreading and binding of fibrin and matrix proteins (Dohan Ehrenfest et al. 2010). A more textured surface thus favours bone cell differentiation, migration, proliferation and attachment. This in turn influences tissue healing particularly directly after implantation which is an important part of the osseointegration process (Dohan

<table>
<thead>
<tr>
<th>1st generation</th>
<th>2nd generation</th>
<th>3rd generation Enhanced / nano-enhanced</th>
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<tbody>
<tr>
<td>Machined surface</td>
<td>Titanium blasted</td>
<td>Hydroxyapatite crystal</td>
</tr>
<tr>
<td>Sand blasted</td>
<td>Sand blasted and acid etched</td>
<td>Genetically enhanced</td>
</tr>
<tr>
<td>Titanium plasma sprayed (TPS)</td>
<td>Dual acid etched</td>
<td>Recombinant BMP</td>
</tr>
<tr>
<td>Hydroxyapatite coated</td>
<td>Electrolyte enhancement</td>
<td></td>
</tr>
</tbody>
</table>

Table 1
Ehrenfest et al. 2010).

Since previous studies have shown that these nanostructures can be of importance in the bone healing process, Svanborg et al. (2009) recently made the first attempt to characterise commercial oral implants not only at a micrometer level, which has been standard procedure up to today, but also at the nanometer level. The authors investigated whether the surface roughness on the nanometer level was correlated to the micrometer roughness of the implants. Their results showed that some of the commercial implants do have structures in the nanometer range of the implants investigated (Svanborg et al. 2009).

Although there have been in vitro and in vivo studies performed on implants marketed as having nanosurface enhancements, little research has been published on human studies using these nanophase implants. This has consequently limited the evidence available to confidently claim that nanosurface implant performance is superior to their predecessors. For this reason, the aim of our study is to review literature that fulfilled the selection criteria.

The present review focussed on literature involving Biomet3i’s Nanotite implant only, with the intention to investigate other implant companies in the near future. It should be noted that selection of the Nanotite implant as a representation of an implant expressing nanosurface technology was purely random and that the authors have no financial interests or associations with this particular company whatsoever.

MATERIALS AND METHODS

Nanotite

The Nanotite implant is Biomet3i’s (Palm Beach Gardens, Florida, USA) “new generation” titanium dental implant that entered the market in the last three to four years. The complexity of the surface topography is increased through a Discrete Crystalline Deposition (DCD”), a process in which nano-scale crystals of Calcium Phosphate are added to about 50% of the Biomet3i’s Osseotite dual acid-etched surface (Mendes et al, 2009). The Calcium Phosphate crystals are between 20-100nm in size (Mendes et al, 2009). Biomet3i’s website [www.Biomet3i.com] state that the resulting undercuts of the nano-scale crystals act as the main driving force for “Bone Bonding” by means of a mechanical interlocking of bone matrix with the Calcium Phosphate crystal modified implant surface.

Search Methodology

Ovid MEDLINE (2000 through September 2010)
EMBASE (2000 through September 2010)
Cochrane database of systematic review (2000 through September 2010)

The search for international peer reviewed journal articles was through the above databases. The search parameters involved human studies reported in English and published between the years 2000 and current 2010 (4/9/2010). The following combinations of search terms and keywords were used: “nanotechnology” OR “nanosurface” OR “nanostructures” OR “topography” OR “surface coating” OR “nanotite” OR “Biomet3i” AND “single implant” OR “single tooth implant” OR “single oral implant” OR “single dental implant” OR “single implant restoration”. The above protocol was carried out in order to obtain research articles on Biomet3i’s Nanotite dental implant used in single implant cases. As we were searching three different databases, some articles appeared in more than one database, these are termed duplicates and were subsequently removed ensuring articles were not accounted for more than once. The resulting articles were manually searched.

Furthermore, bibliographies of research articles from the Biomet3i’s company website were sourced and relevant articles were manually searched. A further database search with terms ”Biomet3i” OR ”Nanotite” was also performed, as the initial database search was inconclusive (Figure 1).

In addition, the reviewers attempted to contact corresponding authors, where appropriate, to confirm data extraction and/or obtain missing data (Figure 1).

Study Selection

The searches were carried out by one author (GB) independently. All types of study designs were included, except for case reports because of their lack of quantitative outcomes (Atieh et al. 2009). Review articles were also discluded, however their bibliographies were searched for any potential articles. No further inclusion criteria for study selection were specified. All duplicates were removed.

Data Abstraction

The following information was retrieved from the selected studies using a specially designed data template:

• Publication details (title, author(s), journal, year, volume, issue number, pages)
• Type of study (ie. clinical trial, review)
• Patient details (sex, age)
• Number of implants placed/participants involved
• Details of the surgical approach
• Treatment modality (ie single unit or multi unit restoration)
• Implant diameter
**FIRST DATA SEARCH**

Database Search A (all fields): EMBASE, Ovid MEDLINE, Cochrane database of systematic reviews:
- “single implant” OR
- “single tooth implant” OR
- “single oral implant” OR
- “single dental implant” OR
- “single implant restoration” (895 articles)

Limit by: English Language, Human Year 2000-current (4/9/10), Removing duplicates (289 articles)

Database search A+B
Results = 4 articles

**SECOND DATA SEARCH**

Database search C (all fields): EMBASE, Ovid MEDLINE, Cochrane database of systematic reviews
- “biomet3i” OR “nanotite” (22 articles)

Limit by: English Language, Human Year 2000-current (4/9/10), Removing duplicates (8 articles)

After removing:
- case reports, review articles, non dental articles
- articles focussing on other aspects of the implant system and implant related procedures (ie abutments, or grafting procedures)

Database search C
Results = 6 articles

Reading full articles to confirm they make the inclusion criteria and omit duplicates

Database search C+D
Results = 2 Articles
DISCUSSION

Through an extensive search on Nanotite’s current use in Dentistry only two articles met our inclusion criteria. These two articles were produced by the same research teams. The Biomet3i website cited other articles as evidence of the success with Nanotite surfaces, however under careful scrutiny there were few human studies available. Of these studies, sample sizes differed and single tooth replacement information provided by the authors was limited. Follow up periods were no greater than one year.

Although somewhat limited in the aforementioned human studies, the Nanotite implant surface featuring application of nanometer-scale calcium phosphate, has been shown to enhance early bone fixation and formation in preclinical and clinical studies.

Table 2

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Östman et al. 2010(a)</th>
<th>Östman et al. 2010(b)</th>
</tr>
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<tbody>
<tr>
<td>Study Design</td>
<td>Prospective</td>
<td>Prospective (multicentre)</td>
</tr>
<tr>
<td>No. of implants/participants</td>
<td>102 implants</td>
<td>355 implants 185 patients</td>
</tr>
<tr>
<td>Age (years)</td>
<td>NA</td>
<td>51.5 (mean)</td>
</tr>
<tr>
<td>Gender</td>
<td>NA</td>
<td>56 %F, 46%M</td>
</tr>
<tr>
<td>Implant length (mm)</td>
<td>8.5, 10, 11.5, 13,15</td>
<td>8.5, 10, 11.5, 13</td>
</tr>
<tr>
<td>Implant diameter (mm)</td>
<td>4 and 5</td>
<td>4 and 5</td>
</tr>
<tr>
<td>Implant location</td>
<td>Mx-7 single implants</td>
<td>Ant Mx-18.4%</td>
</tr>
<tr>
<td></td>
<td>Mn-7 single implants</td>
<td>Ant Mn- 4.7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post. Mx – 26.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post Mn- 50.4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Single implant vs multi-unit implant location not specified)</td>
</tr>
</tbody>
</table>
| Surgical protocol                           | Modified drill technique
                Undersized osteotomies | Different. As 15 different study centres |
| Treatment modality                          | -Multi-unit restorations (64 implants) |
|                                             | -Single-tooth restorations (14 implants) |
|                                             | -Maxillary full-arch fixed prostheses (24 implants) |
|                                             | 216 cases             |
|                                             | -single tooth restorations (128 cases/ implants) |
|                                             | -multi unit fixed prostheses (88 cases) |
| Time to loading /placing of restoration     | Immediate             | Immediate             |
| Observation period                          | 3, 6, 12months        | 6, 12 months (then yearly for 5 years) |
| Measurement of success/survival             | Clinically Radiographically |
| Implant success/survival rate (%)           | 99.2% CSR             | 94.9% CSR             |

NA=not available
in human histomorphometric studies (Goene’ et al. 2007, Orsini et al. 2007), although human histomorphometric data from prospective, randomised, controlled, double-blind studies are understandably restricted.

Orsini et al (2007) enrolled 15 patients (mean age: 56.9 years) with partial or full edentulism, who had elected to receive dental implants to restore their dentition in a study. One custom-made 2mm by 10mm implant with a DCD-modified DAE surface (Nanotite) and one implant with only a DAE surface (Osseotite) was placed in the posterior maxilla of the 15 patients. After a mean healing time of 7-8 weeks, implants and surrounding hard and soft tissue were retrieved by trephine. The mean bone-to-implant contact was 32% for the Nanotite surfaces and 19% for the Osseotite surfaces and was statistically significant. The authors concluded that the DCD treatment increased the osteoconduction of the implant surface during the first 2 months after the implant was placed. They also suggested that DCD surface modification can lead to a shorter healing period once the implant has been placed.

The results of Goene’ et al (2007) are similar to those of Orsini et al (2007). In a prospective randomised controlled trial in humans, nine pairs of implants, with the Nanotite or Osseotite surface, were placed in the posterior maxillae. Three pairs were retrieved by a trephine with surrounding soft and hard tissue following 4 weeks of healing, five after 8 weeks of healing and one pair after 12 weeks of healing. After 4 weeks, there was no significant difference reported between the two implant surfaces. After 8–12 weeks the mean bone-to-implant contact percentages were 45% for Nanotite implants and 18% for Osseotite implants. It was concluded that the DCD modification of Nanotite implants appeared to have a profound effect on the development of new bone following implant placement.

**CLINICAL IMPLICATIONS**

A reduced healing period and increased osteoconduction can enable earlier fixation as well as minimise micromotion, thus allowing immediate or accelerated loading protocols and restoration of function for implants placed in areas with low-density and poor bone quality and quantity (Junker et al. 2009). As preclinical studies demonstrate a substantial improvement on the rate and extent of osseointegration for nanosurface implants compared to their predecessors, there are a number of other potential scenarios where such an implant might be beneficial to patient and practice such as immediate replacement in extraction sockets, simultaneous grafted sites and implant placement, esthetic areas where bone preservation is critical and locations requiring short or wide implants (www.biomet3i.com).

**Review of study one (Ostman et al. 2010[a])**

Ostman et al. (2010a) published a prospective, single-centre clinical study that clinically and radiographically evaluated the outcome of the Nanotite implant when used for immediate loading of multiple fixed prostheses and single-tooth restorations in a patient group with an initial implant stability corresponding to an Implant stability quotient (ISQ) value of 55 and final torque of 25Ncm.

Bone quality and quantity were assessed according to Lekholm and Zarb’s criteria (Lekholm & Zarb 1985) and implants were placed in underprepared osteotomies to increase initial stability (Ostman et al. 2006). Selection of the final drill size was based on bone quality and a countersinking technique was utilised in order for the implant to engage as much cortical crestal bone as possible. Resonance frequency analysis (RFA) measurements were performed to then assess implant stability.

Although this study included multiple fixed prostheses and single-tooth restorations, single tooth implant location and length were not specified. Additionally, marginal bone loss was presented combining both multiple fixed prosthesis and single tooth restorations; six implants showed more than 1mm of bone loss after one year, but it was not clear what sites these implants were placed in. Implant stability quotient (ISQ) measurements were recorded at implant placement and at 6 months when the temporary prosthesis was removed, but further measurements at the one year recall are not stated.

Success was evaluated using a four-field table according to Albrectsson & Zarb (1993) using the following categories: Success, survival, unaccounted for, failure:

1. Success-An implant meeting with success criteria. Criteria for success according to Albrectsson and Zarb (1993) include absence of implant mobility and absence of pain and neuropathy. Also, 1 mm of bone loss from the implant head was acceptable during the first year and less than 0.2 mm bone loss annually thereafter. Less strict criteria were used in the study by Ostman et al. (2010a) since implants were individually tested for mobility only after 3 months and not later. Success grade 1 was defined as an implant with no clinical and radiographic signs of pathology showing less than 1 mm of bone resorption at 1 year of follow-up whereas success grade 2 was defined as an implant with no clinical and radiographic signs of pathology showing less than 2 mm of bone resorption at 1 year of follow-up.

2. Survival-An implant still in the bone that does not meet with or has not been tested for success criteria.

3. Unaccounted for-An implant in a patient who dropped
out of the study for any reason.

4. Failure—An implant removed for any reason.

According to Ostman and colleagues (2010a) the overall cumulative success rate for implants was 99.2% after one year, with one representing failure by showing rotational mobility after three months. The failed implant showed no radiographic signs of loss of integration and was part of a three unit bridge. However based on radiographs and clinical examinations, success grade 1 was applicable for 93%, survived 6%, unaccounted for 0% and failed 1%. Although two single provisional crowns were noted to fracture and had to be rebuilt, there was no distinguishing between success of single implant restorations (which we were interested in) versus those being used for multiple fixed prostheses.

The marginal bone levels were evaluated from digital periapical radiographs by a radiologist. A silicone index material with an individually constructed radiograph holder for each participant was used. Periapical radiographs were exposed after implant surgery to establish baseline, at six months and at one year of function. Crestal bone loss was determined by measuring the distance from the implant/abutment junction (IAJ) on the mesial and distal aspects to the level of the margin of the crestal bone. Bone loss was presented as the mean values for distal and mesial changes from baseline for each implant and each time point. At baseline implant placement, the mean crestal bone level was 0.19 mm (SD 0.3) below the IAJ, and after one year of loading, the level was 0.56 mm (SD 0.37) from the IAJ. The average bone loss for 102 surviving implants was calculated to be 0.37 mm (SD 0.39) after one year of follow-up. Six implants showed more than 1 mm of bone loss, and no implants showed more than 2 mm of bone loss after 1 year. However, bone level measurements presented in this study included both single implant and multiunit implant restorations without distinction.

The authors state that other factors which could contribute to the good outcome of their research are: the modified drilling protocol aiming for high primary stability; the macroanatomy of the Prevail implant and implant surface used. This may suggest that the success seen in this study may be due to a combination of various determinants and not only to implant surface modification.

**Review of study two (Ostman et al. 2010b)**

In the one-year interim report by Ostman et al. (2010b) on the prospective multicentre study on the “immediate provisionalisation in support of single-tooth and unilateral restorations”, one hundred and eighty-five patients in 15 international study centres received a total of 335 implants of which 128 were single-tooth implants.

The study had no restrictions on bone quality and quantity and researchers were directed to reference bone density by recording it as soft, normal or dense according to the clinician’s tactile assessment during osteotomy preparation. However it was reported that about 80% of implants were placed in normal or dense bone.

Standardised periapical radiographs are implicated in the study to indicate perimplant radiolucencies and crestal bone levels at 6 months following implant placement and yearly for 5 years, however findings of any radiographs of the 128 single tooth implants taken at any follow-up period are not presented in the study. Similarly this one year report does not present records of bone levels even though the study states that it would analyse bone levels at 6 months. Information regarding how periapical radiographs were standardised is not presented.

Implant survival is based on the absence of persistent signs and symptoms of pain, infection, paresthesia, inflammation, and implant mobility, with no clarification on how each of these symptoms were assessed. At one year 17 implants in 11 patients had been declared failures for an overall implant cumulative survival rate (CSR) of 94.9%, with the exact CSR for single tooth implants alone being 94.5% (7 failures out of 128 single tooth restoration implants).

It is noteworthy that 53% of NanoTite implants were restored with a pre-surgical approach and that in-house laboratories were available for nearly half of all procedures. For the presurgical approach, “an indirect impression is taken with construction of a prosthesis that is relined and cemented onto the abutments at the time of the implant placement surgery” (Ostman et al. 2010b). Investigators who selected abutments intended for permanent prostheses, avoided the need for removal and reconnection which is thought to promote increased regressive crestal bone remodelling (King et al. 2010). Ostman and colleagues (2010b) deem this as an advantage and hence suggest that it may facilitate procedural success.

The authors also note that the occlusion on most of the provisional prostheses lacked direct occlusal contacts. However claim that because their subjects experienced forces generated during mastication, from surrounding soft tissues and the musculature of the tongue, functional loads were delivered on these prostheses and therefore the study’s immediately provisionalised implant is also an immediately loaded implant. It is important to consider this information when comparing success and survival rates of different studies as the magnitude of occlusal forces that a prosthesis experiences can greatly affect its success, especially in the early stages after implant placement when osseointegration
hasn’t fully completed.

Furthermore, a recent consensus conference recommended that further prospective clinical trials with large patient numbers are urgently needed to provide definitive data on the effectiveness of immediately loaded single tooth restoration implants (Wang et al. 2006).

Standardisation of future implant studies is needed

The present review was concentrated on investigating Biomet 3i therefore this review has limited impact. Unfortunately, at this stage it seems there is little literature available from other companies on their nanosurface implants which warrants their investigation and comparison. Nevertheless further information on these new nanosurface implant’s chemical and physical characteristics is needed. Size, shape and width of implants as well as site placement all have an effect on implant success, therefore it is of paramount importance to have this information when comparing different implants. Standardisation of research would mean that implants could be effectively compared and thus this field of dentistry could advance at a much greater rate.

Until now, implant surfaces have been classified by the way they are produced (e.g. grit-blasting, anodisation, acid-etching) and not by their chemical and physical features (Coelho et al. 2009). Consequently, in many studies surface characterisation is not as thorough as one would like it to be which has resulted in limited data and difficulty in cross-evaluating the numerous studies available and conducting meta-analyses (Wennerberg & Albrektsson 2009).

It should become possible to compare data from the literature in a relevant and standardised way by using a simple characterisation code for each tested surface which will help investigators to better understand and interpret published results (Dohan Ehrenfest et al. 2010). This tool might be especially useful to establish an inventory of surface-related osteogenic behaviours, particularly in the field of bone tissue engineering that requires an accurate library of knowledge (Lovmand et al. 2009).

Dohan Ehrenfest and colleagues (2009), recently presented such a standardised characterisation code for osseointegrated implant surfaces. This code describes the chemical composition of the surface such as the core material and its chemical or biochemical modification through impregnation or coating. This code also defines the physical surface features, at the micro- and nanoscale, such as microroughness, microporosity, nanoroughness, nanoparticles, nanopatterning and fractal architecture. This standardised classification system will allow investigators to clarify unambiguously the identity of any given osseointegrated surface and help to identify the biological outcomes of each surface characteristic. It is therefore a system that should be adopted and implemented by all academics performing implant research.

CONCLUSION

Evidently, the currently available methods to modify implant surface composition at the nano level as demonstrated through the Nanotite surface, cannot be concluded to show greater success and survival than their predecessors at this point in time, although their potential to control the biological activity of the implant surface does warrant further investigation. Thus, additional human studies are needed to provide more insight into a predicted bone response. Standardisation of future implant studies is necessary.

Conflict of interest and source of funding statement:

No external funding, apart from the support of the authors’ institution, was available for this study and the authors declare that there are no conflicts of interest in this study.

CLINICAL RELEVANCE

Scientific rationale for study: The introduction of “modified” implant surfaces has broadened treatment strategies in dental implantology. Benefits of the new generation nano-enhanced implants show further promising success and survival rates in preclinical studies and thus suggest positive benefits over their predecessors, such as shortened healing times and earlier implant loading. Human studies on these surfaces are however limited.

Principal findings: Nanosurface-enhanced implants seem to be a viable option in implant rehabilitation and perform comparatively well to other immediately loaded implants with various surface modifications when immediately provisionalised with single tooth restorations. However additional studies, as well as studies of longer duration are needed.

Practical implications: Nanosurfaced implants, such as Nanotite, show potential to control the biological activity of the implant surface as demonstrated in preclinical studies. However the author’s research showed similar evidence of superior success and survival rates on human studies than other implant surfaces, suggesting additional human studies with longer follow-ups are needed to provide more insight into a predicted bone response.
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