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Research Paper
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Resonance frequency measurements of implant stability in the dog mandible: experimental comparison with histomorphometric data

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Abstract. The aim of the present study was to test the hypothesis that measurements of implant stability using resonance frequency analysis (RFA) correlate with histomorphometric data of bone anchorage.

Ten adult female foxhounds received a total of 80 implants in their mandibles 3 months after removal of all premolar teeth. At the time of implant placement, torque required for bone tapping was registered as a measure of bone density and immediately after placement implant stability was assessed using RFA. RFA measurements were repeated at the time of implant retrieval after 1 month (5 dogs) and 3 months (5 dogs). Peri-implant bone regeneration was assessed histomorphometrically by measuring bone–implant contact (BIC) and the volume density of the newly formed peri-implant bone (BVD).

RFA values at the time of implant placement did not correlate with the torque required to tap the bone for implant placement. After 1 and 3 months, RFA values were significantly increased compared with baseline values. BIC and BVD, however, had increased significantly during this interval. There was no correlation between bone–implant contact and RFA values nor between peri-implant bone density and RFA values. Thus, the hypothesis could not be verified.

It is concluded that the validity of the individual measurement of implant stability using RFA should be considered with caution.

Keywords: implant stability; bone–implant contact; insertion torque; histomorphometry; resonance frequency.

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Recent trends in implant therapy have promoted shortening of treatment time by early loading, immediate loading or at least immediate provisionalization of the placed implants[1,7,13,14,19]. The decision whether or not to continue with one of these treatment options at the time of implant placement is based on the assessment of implant stability. A number of approaches have been developed to measure implant stability using both invasive and non-invasive means. Assessment of removal torque and histomorphometric evaluation of implant–bone interface provide reliable data on the strength of the interface and the quality of implant anchorage in peri-implant bone. These destructive measures are only applicable in an experimental environment. Clinical settings require non-destructive techniques to determine the stability of an implant in its peri-implant bone. In recent years, the analysis of resonance frequency (RFA) of implants has been advocated to measure implant stability in a non-destructive way. This approach uses a transducer that is fixed to the implant and vibrated using a piezoceramic element with a frequency range from 5 to 15 KHz[22,23]. The resulting vibration of the abutment–implant system produces a sharp increase in amplitude when the resonance frequency of the system is reached. This resonance frequency changes according to the stiffness of the excited abutment–implant system. Increasing bone anchorage of an implant would alter the resonance characteristics because of changes in stiffness of an abutment–implant system in its peri-implant bone. Thus, changes in resonance frequency of an implant could indicate changes in anchorage of the implant and allow for conclusions on implant stability in a non-invasive manner. Many experimental and clinical studies have shown an increase in RFA values during implant healing and have attributed this to increasing implant stability related to increased bone anchorage[24,25]. There are a number of studies that have tried to verify parameters that affect RFA values in various settings[2,3,9,10,16,17,26,27]. Unfortunately, no clear picture could be derived from these data regarding the validity of RFA in the assessment of implant–bone anchorage as expressed by bone–implant contact rate or peri-implant bone density.

It was, therefore, the aim of the present study to test the hypothesis that measurements of implant stability using resonance frequency analysis correlate with histomorphometric data of bone–implant anchorage.

Materials and methods

This experimental study was performed on 10 adult female foxhounds (average weight approximately 31.0 kg). The dog mandible was chosen, because it is established as a model for peri-implant bone regeneration under clinically relevant conditions[5,20,30]. Experimental screw-type implants of 4 mm diameter with 3 longitudinal grooves were placed into the alveolar crest of the premolar area 3 months after removal of all premolars (Fig. 1). Implants with 8 different surface modifications were used:

1. Titanium screw implants with a machined surface;
2. Titanium implants with a sandblasted and acid-etched surface;
3. Titanium screws with a collagen I coating;
4. Titanium implants with a collagen I coating;
5. RGD peptide coating at 2 different concentrations (100 and 1000 μmol/ml);
6. Titanium implants with a biomimetic calcium phosphate coating;
7. Titanium implants with a composite coating of calcium phosphate and collagen;
8. Titanium implants with a surface coating of collagen and chondroitin sulphate and BMP2.

The morphological features and the quantitative results of the different surfaces have been previously described, and detailed analysis and discussion of histomorphometric results have been presented elsewhere[31–33]. The aim of this study was to analyse the relation between resonance frequency measurements, insertion torque and histomorphometric parameters.

Four implants were placed on each side of the mandible. During placement the torque required for tapping of each implant bed was registered (Osseocare® Nobel Biocare, Sweden). Care was taken to place the implant in a defined vertical position, so that the implant body was fully buried in bone with the cover screw at the level of the bone surface of the alveolar crest. After implant placement, RFA values were recorded for each implant (Ostell® Integration Diagnostics, Sävedalen, Sweden) as ISQ values, cover screws were placed and the wounds were closed with resorbable polyglactin sutures. ISQ is close to linear mapping of the Hz scale of the original frequency values and has been introduced to compensate for different abutment and transducer lengths. Following surgery, the dogs were inspected daily and oral hygiene procedures were performed once a week. After 1 month and 3 months, the implants of 5 animals each were evaluated. This means that 40 implants were evaluated after a healing period of 1 month and 40 implants after 3 months.

At the time of retrieval, mucosa overlying the cover screws and the cover screws themselves were removed and RFA values were recorded. Mandibular segments containing the implants were retrieved and fixated immediately in 4% buffered formalin. The implants were located radiographically and the mandibular bone was then separated using a diamond-coated saw (Fa. Exakt, Norderstedt, Germany) into segments that contained one implant each. The individual implants with surrounding bone were embedded in methylmethacrylate resin. Undecalcified thick sections (thickness 30–70 μm) of the embedded specimens were fabricated with a diamond-edged blade in a rotating saw (Fa. Leitz, Hamburg, Germany) perpendicular through their long axis. The resulting specimens were surface stained using Toluidine Blue and Masson–Goldner staining.

Histomorphometry was performed using a video camera (Sony 3CCD; Germany) to record images at 50× magnification. The images were digitized (Axiophot-System, Zeiss, Obercochem, Germany) and the bone–implant contact (BIC) was measured by counting all pixels of the implant contour occupied by bone. It was expressed as a percentage of the perimeter of the implant cross section. The volume density of the newly formed peri-implant bone (BVD) was assessed by calculating the percentage

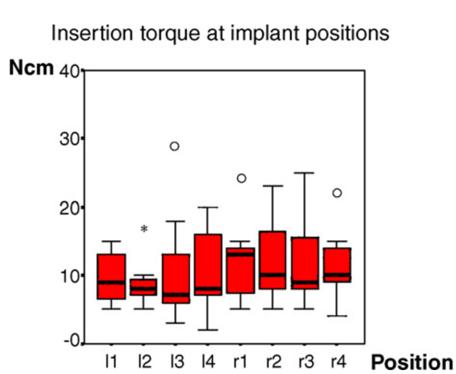

Fig. 1. Insertion torque during pretapping in the different areas of the mandible.