Mandibular implant-retained overdentures can provide an effective treatment for patients with edentulism and, in particular, those who have persistent problems using conventional mandibular prostheses. The use of 2 interforaminally-placed implants to support such overdentures was demonstrated to be clinically successful, economically advantageous, and provided adequate retention. Different kinds of attachments could be used to retain this prosthesis. Solitary ball attachments were claimed to be less technique sensitive, less costly, and easier to clean compared with bar attachments.

Immediate loading of dental implants has long been used to shorten treatment time and to provide a solution for interim restorations, which enhanced patient satisfaction. Although research has shown no difference in implant stability and implant failure rates with delayed and immediate loading protocols, several factors could affect the results of the immediate loading protocol, including the surgical technique, primary implant stability, bone quality and quantity, wound healing, implant macrostructure, and prosthetic design. Successful osseointegration of immediately loaded implants depended on keeping the load from generating excessive micromotion at the bone-implant interface, which was determined experimentally to fall between 50 and 150 μm. The refinement of the clinical protocols, the application of sound biomechanical principles, and the introduction of new implant designs and surface treatments encouraged the successful use of this loading protocol, especially in implant overdentures. In an

ABSTRACT

Statement of problem. The use of soft liners as female receptacles for ball attachments retaining immediately loaded implant overdenture has been recommended to enhance osseointegration and provide a shock absorbing effect. However, which liner and which thickness is still unclear.

Purpose. The purpose of this finite element analysis (FEA) study was to evaluate the effect of a 2- and 4-mm thickness of thermoplastic resin (TRL) and silicone-based liners (SBL) on the displacement and stresses transmitted to immediately loaded implants retaining a mandibular overdenture.

Material and methods. Four 3-dimensional (3D) FEA models of a mandibular implant overdenture retained by 2 ball attachments (2 models for each lining material with 2- or 4-mm liner thicknesses) were developed. Implants were placed in the canine regions and surrounded by a 1-mm cylinder of immature bone simulating immediate loading. A vertical and an oblique load of 150 N were applied in the right premolar molar regions. Stresses and displacement were set as output variables.

Results. Replacing the TRL by the SBL was associated with a decrease in stresses by 73% and in displacement by at least 46%. Increasing the thickness of any liner decreases stresses by 45% during vertical loading and by 25% during oblique loading and decreases displacement by 61.5% during vertical loading and by an average of 32.5% during oblique loading. None of the liners exceeded the experimental risk limits for micromotion at the bone-implant interface (50 μm).

Conclusion. In immediately loaded mandibular implant overdentures, both SBL and TRL decrease the micromotion of implants and the stresses at the bone-implant interface. However, SBL is more effective. The thickness of both liners seems to play a major role in decreasing the stresses and displacement of periimplant tissues. (J Prosthet Dent 2016;116:356-361)
Catalysts, and materials differ in the percentage of cross-linking agents, resins and silicone elastomers. In each type, the available restoration or early loading is attempted.

Grafted bone or bone of poor quality, or when an interim use is mainly indicated when implants are placed in previously selected treatment plan; however, short-term has a mild inhibitory effect on addition, the acryloxyalkylsilane additive in some of them and less wettability than acrylic resin-based liners. In materials.21,22 They are available in autopolymerizing and heat-polymerizing forms.18

Soft liners are also simple, inexpensive, and easy to replace. The use of a soft liner–retained, implant overdenture also solves many treatment problems when the number, location, size, or angulation of dental implants placed differ from the original treatment plan. Its use may be for short or long term.17 Long-term use could be related to a change in the previously selected treatment plan; however, short-term use is mainly indicated when implants are placed in grafted bone or bone of poor quality, or when an interim restoration or early loading is attempted.

The 2 main types of soft liners are plasticized acrylic resins and silicone elastomers. In each type, the available materials differ in the percentage of cross-linking agents, catalysts, and fillers. They are available in autopolymerizing and heat-polymerizing forms.18

Silicone based liners (SBL) are elastomeric polymers (polydimethylsiloxane) that do not require an external plasticizer and are, therefore, more stable over time than acrylic based liners. They serve as definitive liners since they have low water sorption properties, satisfactory adhesion to the denture base because of the presence of benzyl peroxides, significantly better rupture properties, and less wettability than acrylic resin-based liners. In addition, the acryloxyalkylsilane additive in some of them has a mild inhibitory effect on Candida albicans growth.19

Their main disadvantages are related to their low glass transition temperature and to their hydrophobicity, which reduces their water sorption but simultaneously inhibits good affinity to the supporting tissues.20

Thermoplastic resins have been available since 1950 and have recently been used as resilient denture lining materials.21,22 They are flexible biocompatible materials with a reported, predictable, long-term performance, durable bonding to acrylic resin denture bases, high fatigue endurance, excellent wear characteristics, and solvent resistance, with almost no free monomer in the processed material. The absence of porosity in the material reduces the biologic buildup, water sorption, odors, and stains, thereby allowing better dimensional and color stability than conventional resins.23,24

The ideal thickness of the liner has long been a controversial issue.25-27 Some authors have advocated the use of the FEA to study the stresses transmitted to the implants and their surrounding structures.28,29 Hence, this FEA was performed to evaluate the effect of 2- and 4-mm thicknesses of thermoplastic resin liner (TRL) and SBL on the displacement and stresses transmitted to immediately loaded implant-retained mandibular overdentures.

MATERIAL AND METHODS

A 3-dimensional (3D) finite element analysis (FEA) model of a mandibular implant overdenture retained by 2 ball attachments and lined with 2 different resilient liners was created. Implants were placed in the canine regions and immediately loaded. The effect of 2- and 4-mm thicknesses of the TRL versus SBL on the stresses transferred to the bone surrounding the implants (measured in MPa) and the implant displacement (measured in mm) was evaluated. The computer simulation of the suggested clinical situation used a personal computer with a core (I7) processor, a cache memory of 6 GB, and a RAM of 4 GB (HP Probook 4540s; Hewlett-Packard Development Co, LP) and software (Image Materialise Mimics, Materialise; INUS Technology, Inc, RapidForm XOR3; INUS Technology, Inc, Solidworks 2012 SP0.0 premium package; SolidWorks Corp).

Computed tomographic (CT) images of a dentulous mandible were introduced into the Mimics software. Bone and tooth thresholds were chosen to aid in the 3D calculation to produce the nonmodifiable stereolithographic (STL) or FEA model. The latter was then introduced to intermediate software, RapidForm XOR3, to make multiple cross-sectional curves at the level of the bone and crown of the teeth. These curves, called nonuniform rational basis spline (NURBS) curves, were used to design the fully modifiable computer-aided design (CAD) model, a process called NURBS-based modeling. A number of curves were successively drawn by following the created bone section planes. These included a mucosa of 1 mm, a liner of 2 or 4 mm thickness, and the denture base (Fig. 1A). These basic sketches of the bone, mucosa, denture base, and teeth were modeled with the aid of software (SolidWorks 2012 SP0.0 premium package; SolidWorks Corp). The mathematical model was characterized by an
intercondylar distance of 112.6 mm. At the implant site (canine regions), the bone height was 32 mm and the buccolingual width was 8 mm. The distance between the chin and the mandibular angle was 91 mm, and the distance between the mandibular angle and the coronoïd apophysis was 61 mm. The separation between implant centers was set at 32 mm straight from canine to canine. Because the CT scan image of the artificial tooth material was not as defined and clear as that of natural teeth or bone, the teeth of the dentulous mandible were used to guide the NURBS-based modeling of the denture teeth.

The implant was then modeled separately with the aid of SolidWorks with a length of 12 mm and a diameter of 3.6 mm surrounded by a 1-mm cylinder of immature bone to simulate a situation of immediate loading. This standardized the measurement of the stresses in a constant bony area of 4.6 mm diameter (1 mm larger than the implant diameter).

The components were assembled, creating 4 models, 2 for each lining material, each with 2 different liner thicknesses. All materials used in the models were considered homogenous, isotropic, and linearly elastic. The modulus of elasticity and Poisson ratio for the different materials were introduced into the software following the data listed in Table 1.30-36

All components were considered to have bonded contacts, which means that they were displaced as 1 unit and did not penetrate each another; however, there was a slip contact between the ball head and the liner material and between the implant and the immature bone.36 In this study, tetrahedral solid elements were used to form a fine solid mesh with 107 460 elements and 159 553 nodes, which were concentrated at the bone-implant interface. Curvature based mesh was used to involve the different components sizes.

The models were restrained at the inferior and posterior borders of the mandible to prevent its displacement (Fig. 1B). A vertical force of 150 N was applied axially on the central fossae, and a 25-degree oblique force was applied on the buccal slopes of the lingual cusps of the premolar and molars. The maximum von Mises stresses on the jaw bones and the maximum displacement of the implant-abutment complex were set as output variables to evaluate the effect of the different thicknesses of the different resilient lining materials on the immediately loaded implants. The analyses were run using the software (SolidWorks 2012.SP0.0 premium package; SolidWorks Corp), and the results were recorded.

**RESULTS**

Generally, stresses were concentrated on the loaded side, with minimal stress propagation to the unloaded side.
(Fig. 2). For all models, the von Mises stresses, recorded under oblique loading, were higher than those recorded under vertical loading. This is attributed to the analysis of the oblique into vertical and detrimental lateral loads. At the implant level, the highest stresses were found in the coronal portion of the periimplant bone of the loaded side. Stresses then faded massively as measured further apically along the whole implant length. This was especially true for the SBL models. However, in the TRL models, stresses were concentrated along the coronal two-thirds or even more of the implant length, starting to fade only at the implant apex (Fig. 3).

As listed in Table 2, increasing the thickness of any of the liners from 2 to 4 mm decreased the stresses by 45% during vertical loading and by 25% during oblique loading. Stresses also decreased by 73% if the liner was changed from TRL to SBL during both oblique and vertical loading. However, increasing the thickness of any of the liners from 2 to 4 mm decreased the displacement by 61.5% during vertical loading and by an average of 32.5% during oblique loading. Also, displacement was decreased by 46% when the liner was changed from TRL to SBL during vertical loading and by an average of 51% during oblique loading. Furthermore, a positive linear and exponential correlation was found between the maximum equivalent stresses in the periimplant bone and the implant displacement values with a Pearson correlation coefficient of 0.946 (Fig. 4).

**DISCUSSION**

Placing resilient liners around dental implant abutments improves the retention and stability of implant overdentures and more importantly minimizes the possibility of overloading the implants, not only by acting as a shock absorber but also by compensating the volumetric contraction of the acrylic resin denture base that occurs during processing, thereby preventing the implants from coming into direct contact with the acrylic resin.

The results of this FEA study confirmed a decrease in the stress and implant displacement values, whatever the liner material or thickness used. None of the investigated lining materials produced displacement values exceeding 50 µm, which was reported to be the experimental risk limit for micromotion at the bone-implant interface and which should be avoided whenever immediate loading of implants is attempted. This together with the positive
AND BY AN AVERAGE OF 32.5% DURING OBLIQUE LOADING. THIS DECREASED DISPLACEMENT BY 61.5% DURING VERTICAL LOADING

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SPREAD OVER A LARGER AREA OF THE LINING MATERIAL WITH LESSER HIGHER ENERGY ABSORPTION, WHICH ALLOWS THE LOAD TO BE

DECREASED IN THE STRESSES BY 73% AND IN THE DISPLACEMENT RELATED TO THE RELATIVELY HIGHER DISPLACEMENT VALUES OF THE IMPLANT ASSOCIATED WITH THE TRL AND WHICH, THEREFORE, GENERATED HIGHER STRESSES APICALLY.

FEA STUDIES HAVE BEEN WIDELY USED IN THE FIELD OF IMPLANT DENTISTRY TO ELIMINATE MANY VARIABLES AND TO AVOID ETHICAL AND METHODOLOGIC LIMITATIONS. HOWEVER, THE METHOD IS BASED ON A SET OF INPUT VALUES THAT ARE ASSUMED TO BE AVERAGE VALUES AS OCCLUSAL LOADING, BONE, MUCOSA, AND LINER MECHANICAL PROPERTIES. ALL MATERIALS WERE ASSUMED TO BE HOMOGENEOUS AND ISOTROPIC, ALTHOUGH SOME MATERIALS SUCH AS THE CORTICAL BONE ARE ACTUALLY ISOTROPIC BUT NONHOMOGENEOUS. THIS FACTOR, TOGETHER WITH THE ARCH SHAPE AND DIMENSIONS, IMPLANT POSITIONS, AND ANGULATIONS, COULD AFFECT THE RESULTS. IN ADDITION, THE LINEAR RELATIONSHIP OBSERVED BETWEEN THE STRESSES AND IMPLANT DISPLACEMENTS COULD ONLY APPLY TO THE RANGE OF VARIABLES CONSIDERED HERE, BUT AN EXPANDED RANGE MIGHT SHOW A DIFFERENT RELATIONSHIP. HENCE, RANDOMIZED CLINICAL TRIALS ARE NECESSARY TO DEMONSTRATE THE EFFICIENCY OF SOFT LINERS IN IMMEDIATELY LOADED IMPLANT OVERDENTURES.

CONCLUSIONS


REFERENCES


