Creation and validation of a novel implant attachment for full-arch prostheses

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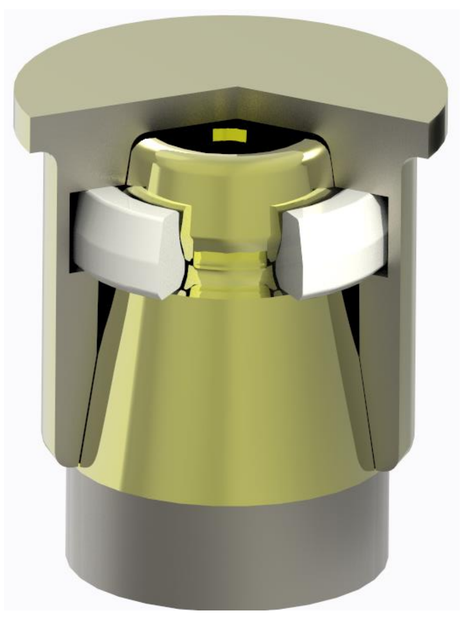
PURPOSE

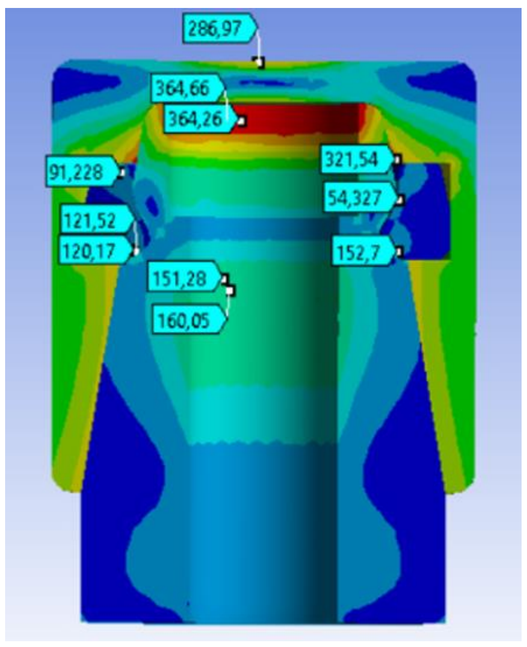
The major problem with full-arch prostheses consists in their hygienic maintenance, which is a very demanding and expensive task; the effective control of bacterial biofilm and plaque is the key factor for the long-term stability of peri-implant soft tissues and bone. The aim of this study was to design, prototype and characterize a new prosthetic attachment suitable for full-arch prostheses with purely implant support; the attachment was designed to fulfill the requirements of a high prosthetic stability (similar to that of conventional fixed prostheses) and a greatly improved hygienic maintenance.

METHODS AND MATERIALS

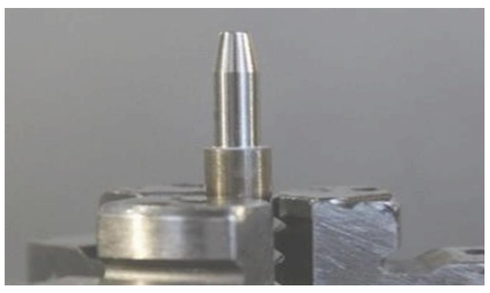
Using Creo Parametrics® software, an innovative conometric attachment concept was designed, which exploits the synergy between a conometric coupling and a resilient retentive element. A finite element analysis (FEA) was performed which confirmed the compatibility of the theoretical project under physiological occlusal loads. All prototypes (n=10) were milled from Ti 6Al 4V rods using computer numerical control (CNC) technologies, except for the retentive groove on the male attachment which was obtained by turning on a manual lathe using a profiled tool. All components have been coated with Ti-N to increase wear resistance. A purposedly built cycling machine (compression and traction) was employed to evaluate the retention force as a function of the number of insertion/disinsertion cycles. A total of 2500 cycles, equivalent to 2.3 years of functional use, were simulated for each sample using axial movements at a frequency of 0.68Hz. Every test was performed with a perfect passivation of the male/female connection in artificial saliva; 5 prototypes received high hardness rings, the other 5 prototypes softer ones. The retentive force values were recorded in continuous mode with a resolution of 15 measurements per second and were related to the cycles number using a load cell connected to a data logger.



Theoretical project: the interaction between conometry and resilience gives rise to retention and stability

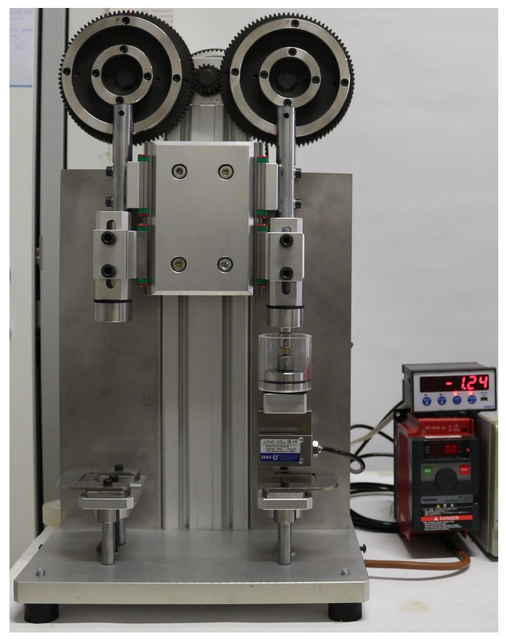


Finite Element Analysis of the components under 360N load



CNC manufacturing of conometric coupling

Manual turning of the retentive groove

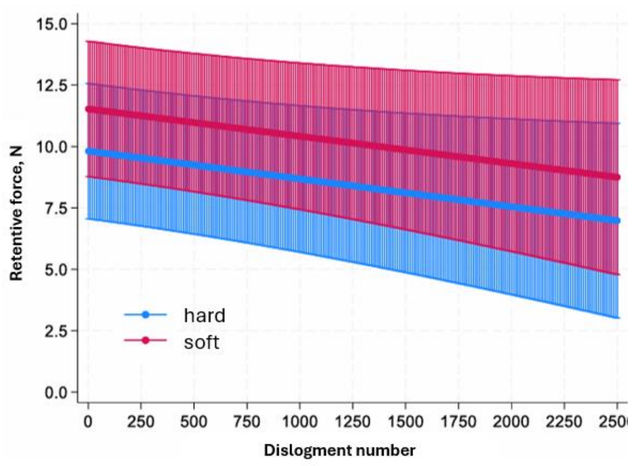


Assembled cyclic machine: measures with extreme resolution the force necessary for prosthetic detachment as a function of time.

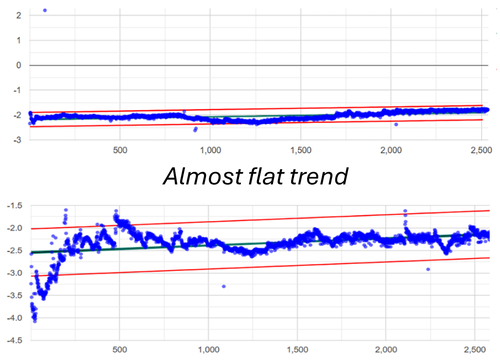
Tests performed with perfect passivation in artificial saliva.

RESULTS

The average retention values were 8 N for the prototypes associated with high hardness elements and 10 N for those associated with medium hardness elements. The total retention in a prosthesis on 4 or 6 implants would thus oscillate between 37 and 55 N. The multilevel linear regression showed a decrease in retention based on time of 1.2 N/year for both groups. However, this value is not significant from a statistical point of view (P-value 0.09). The retention force/cycles correlation within each attachment, thanks to the huge amount of data logged, reached a maximum statistical power of 1.0.
For some prototypes excellent behaviors were recorded (first column of three graphs from the left), with retention losses significantly lower than those reported in the literature ($p < 0.05$). For other prototypes we observed anomalous trends (second column of three graphs from the left) such as retention improvements over time, cyclic retention losses, momentary retention losses.



Multilevel linear regression showed a slight decline in retention based on time



Almost flat trend

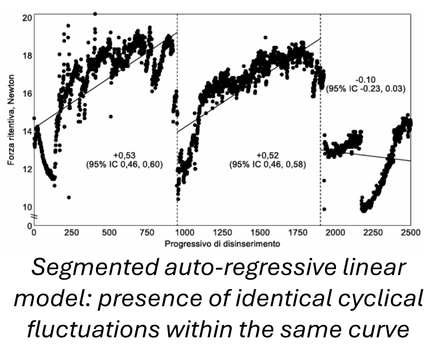
Initial retentive loss and subsequent stabilization

Initial retentive loss and subsequent stabilization

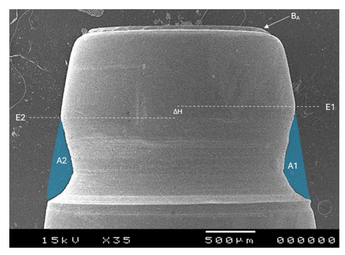
Cyclic retention losses

Retention improvements over time

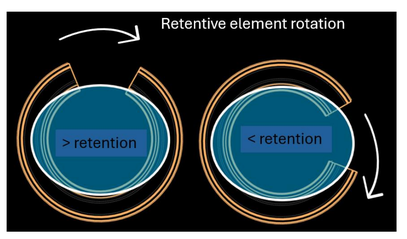
Momentary retention loss



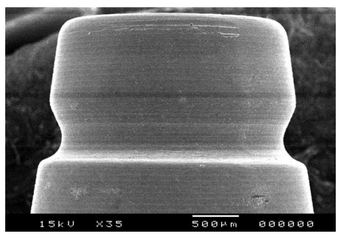
Segmented auto-regressive linear model: presence of identical cyclical fluctuations within the same curve



Prototypes morphological defects of the retentive groove



The rotational theory



Entirely CNC manufactured sample

CONCLUSIONS

An innovative prosthetic attachment that combines conometry and a resilient ring to provide stability and retention has shown great potential for various applications. Tests on the retentive force over multiple insertion and disconnection cycles demonstrated high durability in some prototypes, consistently maintaining this parameter over time. Furthermore, the recorded values of retentive strength were found to be compatible with the clinical objective of constructing full-arch prostheses that are removable by the patient. It's worth noting that the prototypes were produced also using non-CNC technologies, which resulted in minor asymmetries on the active surfaces. These asymmetries introduced some variability in the data, partially obscuring the attachment's excellent performance, which was more apparent in the most symmetrical samples. Moving beyond the prototyping phase, these attachments are expected to offer stable and long-lasting retention for removable and extremely stable full-arch prostheses.

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