Single-tooth Morse taper connection implants after 1 year of functional loading: a multicentre study on 302 patients

Key words  implant–abutment connection, Morse taper connection implants, prosthetic complications, single-tooth restorations

Purpose: This prospective clinical study evaluated the survival rate and the implant-crown success of 314 Morse taper connection implants, used for single-tooth replacement, after 1 year of functional loading.

Materials and methods: Over a 4-year period (January 2003 to January 2007), 314 implants (168 maxilla, 146 mandible) were inserted in 302 patients (128 males, 174 females, aged between 23 to 79 years) in six different clinical centres. The sites included anterior (n = 118) and posterior (n = 196) teeth. To evaluate implant-crown success, the following clinical, prosthetic and radiographic parameters were assessed: modified plaque index (mPI), modified sulcus bleeding index (mBI), probing depth (PD), distance from the implant crown margin to the coronal border of the peri-implant mucosa (DIM), width of keratinised mucosa (KM), prosthesis function, and the distance between the implant shoulder and first crestal bone-implant contact (DIB). Success criteria included: absence of suppuration and mobility, PD<5.0mm, absence of prosthetic complications, absence of continuous peri-implant radiolucency, and DIB<1.5mm after 1-year of functional loading. Prosthetic restorations were all-ceramic (n = 116) and metal-ceramic (n = 198) crowns.

Results: The implant survival rate was 98.4% (5 implant losses, 1 drop-out). A few prosthetic complications (0.6% implant-abutment loosening) were reported. The mean DIB was 0.887±0.308mm. Among the survived implants (308), four did not fulfil the success criteria, giving an implant-crown success of 98.7%.

Conclusion: The use of Morse taper connection implants represents a successful procedure for single-tooth replacement, in the anterior and posterior areas of both arches. The high mechanical stability may reduce prosthetic complications.

Introduction

Loss of a single tooth is predominantly associated with non-physiological occlusion, resulting from tipping of neighbouring teeth and extrusion of opposing teeth. Moreover, in the anterior tooth region emotional and aesthetic problems may occur due to the loss of a single tooth. The application of endosseous implants for the restoration of single missing teeth has been reported in a large number of studies, with follow-up periods of 1 to 8 years showing excellent survival and success rates, varying from 93.7% to 100.0%. For this
reason, the use of dental implants to prosthetically restore function and aesthetics following the loss of a single tooth has become common treatment and standard care and an alternative to conventional tooth-supported reconstruction, mainly due to the benefit of avoiding loss of intact tooth substance of adjacent teeth. Although the high success rate of single-tooth restorations is an accepted clinical reality, many reports of a high incidence of prosthetic and mechanical complications, such as abutment and occlusal screw loosening, have been published. In a 5-year study on 107 single tooth implants, the incidence of abutment screw loosening was 12.7%. In a 2-year study on 81 single-tooth implants, inserted mainly in the posterior areas of both arches and restored with an octa-abutment screw-retained crown, occlusal screw loosening was reported in 22.2% of the implants.

In another 3-year study on 80 single-tooth implants, the most frequent prosthetic complication was loosening of the abutment screw (28%). Evidence of a high occurrence of abutment screw loosening for single-tooth implant restorations has been demonstrated by Balshi et al. (48%) and Ekfeldt et al. (43%). These complications frequently affect single-tooth restorations in the posterior regions of both arches, where the mechanical load is higher, with screw loosening percentages between 6 and 48%.

A major difference between implant systems is the type of implant–abutment connection. At present, the most commonly used methods for securing the abutment to the implant involve screw-type connections. In screw-retained abutment systems, the connection between the implant and the abutment strongly depends on the screw preload, which is generated by applying a predetermined amount of torque during application. When occlusal loads exceed the preload, the screw can loosen or break.

The introduction of the Morse taper implant–abutment connection may represent a possible solution to this problem. The Morse taper implant–abutment connection relies on the large contact pressure and frictional resistance in the region of the implant–abutment interface. Levine et al. reported a lower rate of abutment loosening (3.6% to 5.3%) when conical implant–abutment connections were used, restoring single-tooth replacements with cemented crowns. Sutter et al. proposed a taper connection between implant and abutment as an optimal combination of predictable vertical positioning and self-locking characteristics.

Similar results have been reported by Norton and Felton, who showed that the incorporation of conical connections between implant and abutment dramatically enhanced the ability of the system to resist bending forces. Reports by Muftu and Chapman and Morgan and Chapman seem to confirm that when a Morse taper implant–abutment connection is used, the abutment loosening is less of a problem.

The purpose of this prospective study was to evaluate the survival rate and the implant-crown success of 314 Morse taper connection implants (Leone implant System, Florence, Italy) used for single-tooth replacement.

### Materials and methods

#### Patient selection

Between January 2003 and January 2007, a total of 337 patients, 149 males and 188 females in six different clinical centres, were selected to take part in the prospective clinical study. Inclusion criteria were sufficient bone height and width to place an implant of at least 3.3mm in diameter and 8.0mm in length. Exclusion criteria were: poor oral hygiene, active periodontal infections, uncontrolled diabetes, bruxism, and a heavy smoking habit (more than 15 cigarettes per day). Regarding these criteria, 35 patients could not take part in the study (18 for inadequate bone height and width, 7 for poor oral hygiene, 6 for active periodontal infections, 1 for bruxism, and 3 for a heavy smoking habit).

Three hundred and two patients (128 males and 174 females, aged between 23 and 79 years; average age 52.1 years) fulfilled the inclusion criteria, presenting no conditions listed in the exclusion criteria. For this reason, these patients were enrolled in the prospective clinical study, in six different centres, and were treated with 314 implants (Leone implant System). Twelve patients had bilateral indications for implant therapy. The causes of initial tooth loss were registered according to the following parameters: aplasia (5), unerupted tooth (6), traumatic injuries (26), caries (22), and peri-apical (159) and marginal periodontitis (96). All patients signed an informed consent form.
Preoperative work-up

A complete examination of the oral hard and soft tissues was carried out for each patient. Panoramic radiographs formed the basis for the primary investigation. Where necessary, computerised tomography (CT) scans were used as the final investigation. CT datasets were acquired using a modern cone-beam scanner (i-CAT®, Imaging Sciences International, Hartfield, PA, USA) and then transferred to a specific implant navigation software (Simplant®, Materialise Dental, Leuven, Belgium), to perform a three-dimensional reconstruction of the maxillary bones.

Through this navigation software, it was possible to correctly assess the width of each implant site, the thickness and the density of the cortical plates and the cancellous bone, as well as the ridge angulation. On the basis of this information, surgical templates (Surgiguide®, Materialise Dental) were manufactured. Preoperative work-ups also included an assessment of the edentulous ridges using casts and a diagnostic waxup.

Implant placement

The teeth that were to be replaced were extracted at least 3 months prior to implant surgery in all patients. Therefore, a removable prosthesis was used for temporary rehabilitation in the anterior, aesthetic areas. Local anaesthesia was obtained by infiltrating articaine 4% containing 1:100,000 adrenaline (Ubiestin®, 3M Espe, St Paul, MN, USA). A mid-crestal incision was made in the edentulous area and extended intra-crevicularly around the adjacent teeth. No releasing incisions were used. Full thickness flaps were elevated exposing the alveolar ridge, and preparation of implant sites was carried out with spiral drills of increasing diameter under constant irrigation (2.8mm to place an implant with 3.3mm diameter; 2.8 and 3.5mm to place an implant with 4.1mm diameter; an additional 4.2-mm drill was used to prepare the site for 4.8-mm-diameter implants). Implants were positioned at the bone crest level. In total, 314 implants were positioned by six experienced surgeons (one for each different clinical centre involved in the study).

One hundred and sixty-eight implants (53.5%) were inserted in the maxilla, and 146 implants (46.5%) were inserted in the mandible. One hundred and eighteen implants (37.6%) were placed in the anterior regions and 196 implants (62.4%) were placed in the posterior regions. The most frequently used implant diameter was 4.1mm, with 205 implants placed (65.2%), followed by the 4.8-mm-diameter implants, with 97 implants (30.9%) and the 3.3-mm-diameter implants, with 12 implants (3.9%). Implant length was 8mm (24 implants, 7.7%), 10mm (96 implants, 30.6%), 12mm (145 implants, 46.1%) and 14mm (49 implants, 15.6%). The flaps were repositioned to cover the implants completely and were secured in position by interrupted sutures (Supramid®, Novaxa Spa, Milan, Italy).

Post-operative treatment

All patients received 2g oral antibiotics, each day for 6 days (Augmentin®, Glaxo-Smithkline Beecham, Brentford, UK). Post-operative pain was controlled by the administration of 100mg nimesulide (Aulin®, Roche Pharmaceutical, Basel, Switzerland) every 12 hours for 2 days. Detailed oral hygiene instructions were provided, and mouth-rinses with 0.12% chlorhexidine digluconate (Oral B, Boston, MA, USA) administered for 7 days. Suture removal was performed at 8 to 10 days.

Healing period

A two-stage technique was used to place the implants35. Implants were left submerged with a healing time of 3 months in the mandibular arch and 4 months in the maxillary arch. Second-stage surgery was conducted to gain access to the underlying implants. A mesio-distal crestal incision, limited to the implant site, was placed and the ridge mucosa was elevated to uncover the implant, followed by replacement of the cover screw with a healing abutment. The mucosal flap was adjusted to the healing abutment and then sutured in position.

The impression for crown restoration was taken from the implant level 2 weeks later, and the prosthetic restoration was placed 3 weeks after abutment surgery. Prosthetic restorations comprised 314 single crowns.

Acrylic resin provisional restorations were used to monitor implant stability under a progressive load and
to obtain good soft tissue healing around the implant before fabrication of the definitive restorations. The temporary restorations remained in situ for 3 months, and after this period definitive restorations were placed.

In the aesthetic areas, patients were restored with a cemented all-ceramic crown, whereas in posterior regions, implants were restored with standard abutments and metal–ceramic crowns. The final prosthetic restorations were all-ceramic (n = 116) and metal–ceramic (n = 198) crowns. Restorations were cemented with zinc phosphate cement or zinc-eugenol oxide cement.

Clinical evaluation

The following clinical parameters were investigated, after 1 year of functional loading, for each implant.

Primary outcome measures of the study were as follows.
• Presence or absence of pain or suppuration36-40.
• Presence or absence of clinical detectable implant mobility tested manually using the handles of two dental mirrors36-40.
• Probing depth (PD) in mm, measured using a periodontal probe (PGF-GFSR®, Hu-Friedy, Chicago, IL, USA) on the mesial, distal, buccal and palatal surfaces of the implants. For each implant, the PD value was calculated based on the average of the four measured values38,39.
• Any prosthetic complications. To test prosthesis function, static and dynamic occlusion were evaluated using standard occluding papers (Bausch articulating paper, Bausch, Nashua, NH, USA). For this reason, any prosthetic complications, such as implant-abutment loosening, abutment fracture and ceramic-crown fracture was registered.
• Intraoral peri-apical radiographs were taken for each implant, using a Rinn alignment system (Dentsply Rinn, Elgin, IL, USA) with a rigid film-object x-ray source coupled to a beam-aiming device to achieve reproducible exposure geometry. Two different aspects were evaluated.
  - The presence or absence of continuous peri-implant radiolucency38-40.
  - The distance between the implant shoulder and the first visible bone contact (DIB) in mm38-40, measured with the aim of an ocular grid. With the latter value, crestal bone level changes at 1 year were registered as modifications in the distance from the implant shoulder to the bone level on the mesial and distal implant side. To correct dimensional distortion, the apparent dimension of each implant was measured on the radiograph and then compared with the real implant length41-44.

Secondary outcome measures of the study were as below.
• Modified plaque index (mPI), determined on the mesial, distal, buccal and palatal surface of the implants. For each implant, the mPI value was calculated based on the average of the four obtained values. The following scores were assigned on the basis of the amount of plaque: score 0, no plaque detected; score 1, plaque only recognised by running a probe across the marginal surface of the implant; score 2, plaque visible with the naked eye; score 3, abundance of soft matter36,37.
• Modified bleeding index (mBI), assessed at the same surfaces, as an indicator of the existence and severity of peri-implant gingivitis. For each implant, the mBI value was calculated based on the average of the four obtained values: score 0, no bleeding running a periodontal probe along the gingival margin adjacent to the implant; score 1, evidence of isolated bleeding spots; score 2, blood forming a confluent line on the mucosal margin; score 3, profuse bleeding37,38.
• Distance from the implant crown margin to the coronal border of the peri-implant mucosa (DIM) in mm, measured at the same surfaces. This parameter was investigated to eventually illustrate the presence of soft tissue recession. For each implant, the DIM value was calculated as the mean of the four measured values, and was recorded as a negative value in the presence of a subgingival implant crown margin38,39.
• Width of keratinised mucosa (KM) measured in mm in the buccal site of each implant38.
Criteria of implant survival and implant success

Regarding implant survival rate, an implant has been classified as a ‘survival implant’ if it was still functioning at the end of the study. Implant losses were categorised as failures. The conditions where implant removal was indicated included peri-implant infections with persistent pain or implant loss due to mechanical overload.

To achieve implant-crown success, the following clinical, prosthetic and radiographic success criteria should be fulfilled:

- absence of pain and suppuration
- absence of clinically detectable implant mobility
- PD<5.0mm (for each implant)
- absence of any prosthetic complications
- absence of continuous peri-implant radiolucency
- DIB<1.5 mm after 12 months of functional loading.45

Results

Implant survival

Five implants (in five patients) failed and had to be removed. Three failed implants were in the posterior maxilla and two were in the anterior mandible. All five implants were classified as ‘early failures’, showing clinically detectable mobility and suppuration, as well as continuous radiographic radiolucency, before the time of abutment connection. All of these five implants showed severe and recurrent peri-implantitis, and no implants were lost due to mechanical overload. No other patients suffered from pain or suppuration and no other patients showed implant mobility. One patient (one implant) moved to another city. For this reason, he could not contribute to the study, missing the 1-year scheduled control, and was classified as a drop out. At the end of the study, the overall implant survival rate was 98.4% (308 of a total of 313 implants still functioning).

Implant success

Two hundred and fifty-three implants (82.1%) revealed an mPI score value (based on the average of the four sites’ obtained values) between 0 and 1, whereas 55 implants (17.9%) exhibited a greater amount of plaque, with score values >1. Two hundred and sixty-eight implants (87.0%) revealed an mBI score value (based on the average of the four sites’ obtained values) between 0 and 1, and 40 implants (13.0%) showed a bleeding score >1. For 258 implants (83.8%), PD value (based on the average of the four measured sites) did not exceed 3.0mm; for 48 implants (15.6%) PD was between 3.0mm and 5.0mm; for 2 implants (0.6%), PD was greater than 5.0mm. In 293 implants (95.1%) the DIM (based on the average of the four measured sites) was between -1mm and -2mm (the DIM was recorded as negative in the presence of a subgingival implant crown margin). Twelve implants (3.9%) showed a DIM between 0mm and -1mm, and just 3 implants (1.0%) showed minimal soft tissue recession with a reported DIM >0mm. Only 7.8% of the sites investigated (24 implants) did not exhibit KM, as they were localised within mobile, non-keratinised tissue.

The remaining sites revealed the presence of KM with a width of 1 mm or more. Two prosthetic abutments (in the posterior area of the mandible) became loose. These abutments were reinserted and no further loosening was observed in the period of this study. The overall incidence of abutment loosening was 0.6%. No other prosthetic complications (such as abutment fracture or ceramic-crown fracture) were evident. The radiographic evaluation of the implants revealed a DIB of 0.887±0.308mm, after 1 year of functional loading.

When compared with bone level around implants seen in immediately post-operative radiographs, this value showed little modification. For this reason, all implants that survived completely fulfilled the radiographic success criteria. With regard to these data, among 308 survival implants, only 4 (of 308) did not fulfil the established clinical, prosthetic and radiographic success criteria (2 implants with PD>5.0mm and 2 implants with implant–abutment disconnection), to give an overall implant-crown success rate of 98.7% (Table 1; Figs 1 to 6).

Discussion

Together with proper design of the occlusion and stable osseointegration, a reliable connection between implant and abutment is a fundamental condition for the appropriate functioning and stability of
Fig 1  Implant in the posterior area of the mandible (46). Radiograph at the time of implant–abutment connection.

Fig 2  The crown in situ after 1 year of functional loading.

Fig 3  Control radiograph after 1 year of functional loading.

Fig 4  Implant in the anterior area of the mandible (41).

Fig 5  The crown in situ after 1 year of functional loading.

Fig 6  Control radiograph after 1 year of functional loading.
<table>
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Ant = anterior; Man = mandibular; Max = maxillary; Pos = posterior.

All clinical centres were private practices.

* In centre number 1, one drop-out was present (reason: patient moved to another city). In addition, among all survived implants (188), two implants could not fulfil the parameters for implant-crown success

** In centre number 2, among all survived implants (71), two implants could not fulfil the parameters for implant-crown success

Table 1 Number of patients treated and distribution of implants inserted in the study, for each clinical centre.
implant restorations. The high mechanical stability of Morse taper implant–abutment connections can reduce prosthetic complications affecting single-tooth restorations on dental implants. A lower percentage of implant–abutment loosening has been seen with single-tooth Morse taper connection implants, when compared with the external hex connections, or butt-joint design. This can result in a better long-term stability in the clinical application. In a 6-year study on 233 Morse taper connection single-tooth implant crowns in the posterior areas, Weigl reported a very low incidence (1.3%) of abutment loosening. No other mechanical complications, such as abutment fracture or ceramic crown fracture were described. In an 8-year study on 275 single-tooth Morse taper connection implants, Doring et al. found no abutment loosening. In a 3-year study, with 58 single tooth implants with Morse taper implant–abutment connection, Romanos and Netwig demonstrated evidence of little prosthetic complications (two abutment fractures). These data are confirmed by the authors’ previous 3-year retrospective study on 80 Morse taper connection implants, mainly positioned in the posterior areas of both arches, with a very low incidence of prosthetic complications (3.75%, with only two abutment fractures and one abutment loosening). In a taper connection, form lock and friction are the basic principles. The tapered fit implant–abutment connection system used in this study (Fig 7) is composed of a fixture and an abutment joined together by a self-locking connection due to a Morse taper guided by an internal hexagon. The Morse taper presents a taper angle of 1.5 degrees, and it is able to induce a self-locking connection between the parts. In the present study, with 314 implant supporting single-tooth restorations, only two prosthetic abutments (0.6%) located in the posterior area of the mandible became loose after 1 year of functional loading. These two abutments were reinserted and no further loosening was observed during the study. No other prosthetic complications (such as abutment or ceramic fracture) were observed. With screw-type implant–abutment connections, the marginal bone crest level around two-piece dental implants is generally located 1.5 to 2.0 mm below the implant–abutment connection after the first year of functional loading. Although precise mechanisms of bone loss around dental implants are still poorly understood, some authors have suggested that micro-movements at the implant–abutment interface could lead to bone resorption. In this context, Morse taper implant–abutment connection, owing to its higher mechanical stability, could reduce crestal bone loss around implants. It is noteworthy that all implants with screw-type implant–abutment connections show a micro-gap of variable dimensions (40 to 100 μm) at the implant–abutment interface. This micro-gap is colonised by bacteria, capable of penetrating the internal aspect of implant components. As the implant–abutment connection is located near the alveolar crest, the bacterial leakage and persistent colonisation of the micro-gaps at the implant–abutment interface are responsible for generating a chemotactic stimulus, which initiates...
and sustains recruitment of inflammatory cells. This finally results in the development of a persistent peri-implant inflammation and increased alveolar bone loss\textsuperscript{58-63}. If the absence of an implant–abutment micro-gap should be associated with reduced peri-implant inflammation and minimal bone loss, the Morse taper implant–abutment connection could provide an efficient seal against microbial penetration\textsuperscript{64}. The tapered interference fit significantly reduces micro-gap dimensions (1 to 3 μm) at the implant–abutment interface, providing an adequate biological seal and avoiding any kind of bacterial leakage\textsuperscript{65}. This contributes to a minimal level of peri-implant soft tissue inflammation and can guarantee adequate bone crest stability. Furthermore, it has been demonstrated that the vertical height of bone around an implant depends largely on the formation of the biological width at the implant–abutment interface, to provide space for the connective tissue\textsuperscript{66}. With tapered interference fit, the abutment emergence geometry leads to the platform switching advantages\textsuperscript{67,68} increasing the distance between the micro-gap and the bone crest level. This is a very important aspect, as bacteria are more distant from the bone and it is possible to minimise bone loss\textsuperscript{69-71}. Moreover, another consequence is excellent soft tissue healing, with thicker, larger, better-organised peri-implant soft tissues. This trans-mucosal seal can protect bone crest from resorption\textsuperscript{72-75}. In the present study, the bone level of the fixture was situated 0.887 ± 0.308 mm from the reference point, after 1 year of functional loading. Good soft tissue healing was present, with 268 implants (87.0%) with an mBI score value (based on the average of the four values obtained from the sites) between 0 and 1. These data were confirmed by PD values, with only 2 implants (0.6%) showing PD > 5.0 mm.

### Conclusions

Based on these results and within the limits of this study (i.e. lack of control and statistics calculated at implant level instead of at patient level), it can be concluded that single-tooth Morse taper connection implants can represent a successful treatment option for single-tooth replacement, even in the posterior areas of both arches. The overall implant survival (98.4%) and the implant-crown success (98.7%) after 1 year of functional loading were in agreement with previous studies on single-tooth implant restorations. The lower incidence of prosthetic complications (0.6% of abutment loosening) demonstrates evidence for the high mechanical stability of the Morse taper implant–abutment connection.

### References


