Narrative Review on Clinical Advantages of the Neodent® Morse Taper Connection

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Introduction

When considering dental implants, there are many factors the clinician must consider, including the implant material, surface properties, size and shape. In recent years, however, one of the most important factors is the strength of the implant-abutment connection, and how the type of connection affects the surrounding hard and soft tissues following placement of the implant. Due to the bone remodelling and resorption that occurs after an implant is placed, this, together with considerations such as the distance between implants and the depth of placement, the connection type has become a crucial feature for clinicians, to minimise as much as possible the amount of bone resorption. The quality of the physical seal between the implant and abutment is also important, as any space (or 'microgap') between abutment and implant can increase the risk of bacterial accumulation, and hence the risk of peri-implant inflammation or peri-implantitis.

Certain problems with some external implant-abutment connections (e.g. external hex connection, where the implant has a hexagonal 'key' at the top, onto which the abutment fits), such as fracture or movement of the abutment or screw loosening, as well as microgaps, led to the development of internal connections. The most prevalent of these is the internal hex, where the abutment is fitted into a hexagonal opening within the implant, i.e. the hexagonal 'key' shape is on the end of the abutment and fits into the implant. Although this proved to give greater stability and a more precise interface between abutment and implant than the external hex type, screw loosening can still occur[1], which may be a result of microleakage[2]. From a mechanical point of view, the risk of loosening can be reduced by a connection that introduces a high degree of friction between abutment and implant, such as that produced by a Morse taper connection. This type of connection was invented by Stephen A. Morse in 1864 as a way to join two machine components by the principle of a 'cone within a cone', where both the male and the female connections are tapered to the same degree[3]. Stephen Morse's original Morse taper was a small angle of 2°. The concept has been widely used in engineering, but was adapted for orthopaedic use in the 1970s, most commonly with taper angles between 5 and 18°. It has subsequently been successfully employed in dental implants, many with either an 8° or a 16° angle, due to its numerous advantages in this situation. For example, it offers high stability due to the friction between the abutment and implant surfaces, minimising the level of micromovement and microgap between abutment and implant, creating an effective seal between the two structures[4].

Importantly, because of the stable internal connection, it allows the possibility of 'platform switching', i.e. where the abutment has a narrower diameter than the implant. The concept has been shown to result in significantly lower peri-implant bone loss[5–10]. In particular, the platform switching concept with implants with a Morse taper connection has shown a trend towards less inflammation in the surrounding soft tissues, therefore reducing the possibility of inflammation-associated bone loss[10]. Although the concept was initially discovered by accident, it has since been incorporated into the implant systems design of numerous companies.

The Morse taper connection developed by Neodent®, the Cone Morse (CM) system, has been incorporated in several implant lines, including the Alvim CM, Drive CM and Titamax CM. It has been demonstrated to have an extremely good bacterial seal, high mechanical strength, and excellent crestal bone preservation properties. The long connection also helps with optimal load distribution. Placement of the implant below the level of the marginal bone (subcrestal placement) in combination with the Cone Morse connection transfers the loading forces deeper into the bone, effectively dissipating the forces exerted on the prosthesis and the supporting bone[11]. This serves to reduce the peak stress forces and, by shifting the loading forces away from the bone crest, minimises bone resorption and preserves the marginal bone. The intention of this review is therefore to demonstrate the scientific evidence behind the Cone Morse system, and to show how this translates into clinical advantages for the patient and clinician.

Effective bacterial seal

The presence of any microgap between the implant and abutment when the abutment is placed and tightened may allow the leakage of bacteria. This can result in leakage of bacterial endotoxins through the gap, and/or a peri-implant biofilm that can compromise the health of the surrounding bone and soft tissue and lead to inflammation. An implant-abutment connection that provides an effective seal is therefore necessary to minimise this risk. The Morse taper connection has been shown to provide such a seal, showing lower bacterial counts in microbiological investigations than other types of connection [12, 13] as a result of the frictional locking produced between the tapered abutment and internal implant surfaces [10]. It has also proven to exhibit a lower incidence of bacterial leakage than an external hex system [14] and under dynamic loading conditions [15], and other studies show that pure conical implant-abutment systems show significantly less bacterial leakage than other types of connection [4].

The conical seal of the Neodent® Cone Morse connection is designed to prevent bacterial migration into the implant, and this has been effectively demonstrated in vitro in other studies. For example, dos Anjos and colleagues investigated the ability of a specific bacterial strain to infiltrate Morse taper connections of two different implant systems [16]. They used 30 implants in three groups: 10 Ankylos implants with Ankylos abutment, 10 Neodent® implants with Neodent® abutment, and 10 Ankylos implants with Neodent® abutments. A 0.1 μL suspension of Escherichia coli (E. coli) was placed in the central chamber of each implant, and abutments were placed and tightened according to the manufacturer's recommendations. The implants were subsequently placed in a culture medium (MacConkey broth) in sterile test tubes and analysed for turbidity (indicating bacterial infiltration) after 1, 2, 5, 7, and 14 days. Although the bacteria were still shown to be viable after 14 days, no turbidity was found in any of the samples at any of the time points. The Morse taper connection therefore effectively prevented bacterial infiltration.

It could be argued, however, that a volume of 0.1 μL is inadequate to show any evidence of bacterial leakage. This was addressed by Silva-Neto and colleagues, who evaluated bacterial leakage of E. coli from Neodent® Morse taper implants [17]. The implant chambers were loaded with 0.1, 0.3, 0.5 or

0.7 µL volumes before being fitted with either passing screw abutments or solid abutments. The implants were then immersed in a brain-heart infusion broth for up to 7 days. Implants alone (without abutments) were used as negative controls, while implants (without abutments) with the same volumes of bacterial suspension were used as positive controls. The bacteria were shown to be viable after 7 days, and no evidence of bacterial leakage was indicated with the 0.1, 0.3 and 0.5 µL volumes for up to 7 days. The implants with 0.7 µL all showed evidence of leakage; however, the authors indicated that this volume was greater than the internal capacity of the implants upon placement of the abutments. Again, the Neodent® Morse taper connection proved to be effective at preventing bacterial leakage.

In addition, a later study by Resende and colleagues investigate the possible influence of the prosthetic index on bacterial microleakage [18]. This internal index is sometimes added to Mores taper implants to aid implant installation; however, abutments without an index could be placed on implants with an index, which may increase the space between implant and abutment, allowing bacterial leakage. The authors of this study used a universal post connection with or without prosthetic implant index, and abutment and implant (Neodent® Alvim CM) with index. A Streptococcus sanguinis solution was used to evaluate microleakage from the implant interior, and immersion in a solution of Fusobacterium nucleatum was used to evaluate leakage into the inner implant chamber. For leakage from the implant interior, 90% of the implants in all groups showed no leakage, and none of the implants showed leakage into the inner chamber. The Neodent® Morse taper connection therefore provides an effective bacterial seal, regardless of the presence of the prosthetic index.

Good biomechanical strength

The excellent biomechanical properties of Morse taper implant-abutment connections have been demonstrated in a number of studies. This type of connection provides [4]:

- High resistance to fatigue loads
- Lower stresses on the abutment screw, compensating for high stress and providing protection from overloading
- Resistance to abutment movement under loading
- Greater resistance to torque loss

The Neodent® Cone Morse connection is no exception to this. For example, Coppedê and colleagues evaluated the fracture resistance of the implant-abutment connection of the Neodent® Alvim CM implant system versus the internal hex, parallel wall connection of the Alvim II Plus system [19], and showed the Cone Morse system to be more resistant to deformation and fracture under loading. Ten implant-abutment systems of each type were embedded in a stainless steel cylinder to a depth of 10 mm (to simulate 3 mm of bone resorption) and subjected to oblique compressive loading at a 45° angle to assess the fracture force and the maximum deformation force for each. The maximum deformation force was significantly higher for the Cone Morse system (mean 90.58 ± 6.72 kgf versus 83.73 ± 4.94 kgf; $p = 0.0182$; Figure 1), indicating much higher resistance to bending forces. Crucially, none of the Cone Morse assemblies fractured, while the mean fracture force for the internal hex assembly was 79.86 ± 4.77 kgf. Pessoa and colleagues, using a three-dimensional finite element analysis model of the Neodent® system, also showed that abutment stability is superior with a Morse taper connection compared to implants with an internal or external hex connection [20]. In addition, the von Mises stresses in the abutment screw are lowest with the Morse taper connection compared to internal or external hex, with a notable lack or abutment gap from loading compared to the other connection types.

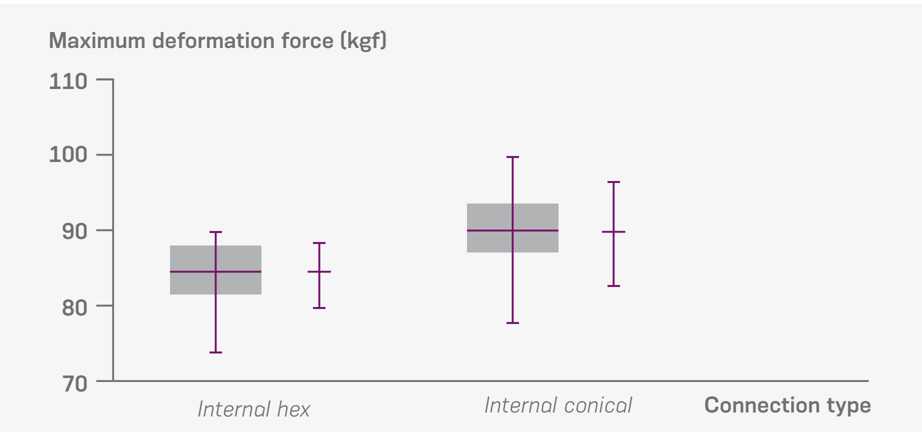

Figure 1: Maximum deformation force values for the internal hex and internal conical systems

The amount of deformation caused by overloading compressive conditions on different diameters of Neodent® Morse taper implants and abutment systems was evaluated by Castro and colleagues [21]. They used implants 3.5 mm, 4.0 mm and 5.0 mm in diameter, each with two-piece abutments, to which strain gauges were attached. The implant-abutment assemblies underwent axial compressive loading (speed 0.5 mm / min) until a force of 1500 N was reached. The load force was chosen based on previous investigations that defined the force necessary to cause deformation in a 5.0 mm Morse taper implant. Under these conditions, 5.0 mm diameter implants showed significantly lower strain than the 4.0 and 3.5 mm implants (650.5 μS ± 170.0 versus 1170.2 μS ± 374.7 and 1388.1 μS ± 326.6, respectively; $p < 0.001$). Strain was therefore reduced by approximately 12.5% between the 4.0 and 3.5 mm implants, and by around 20% between the 5.0 and 4.0 mm implants. The 5.0 mm implants also showed significantly lower strain at the implant-abutment interface than the 4.0 and 3.5 mm implants (943.4 μS ± 504.5 versus 1057.4 μS ± 681.3 and 1159.6 μS ± 425.9, respectively; $p < 0.001$). The authors also noted that strain values reduced by approximately half upon removal of the load for all implant diameters. Based on the results, the authors suggested that 5.0 mm diameter implants would be clinically preferable in situations of high residual strain, such as in male patients with long-term bruxism. However, the authors also noted that all of the implants, regardless of diameter, exhibited clinically acceptable strain values.

Sotto-Maior and colleagues performed a study to assess how apical bone anchorage can affect bone stress and micromovement for subcrestal implants, using the Neodent® Cone Morse Titamax EX system [22]. Three-dimensional modelling was used to simulate 4.0 mm diameter implants placed at bone level, with or without the apex engaged in cortical bone, or 2 mm subcrestally, with or without the apex engaged in cortical bone. Models of abutments (heights of 1.5 mm for the bone level implants and 3.5 mm for the subcrestal implants) and premolar crowns were subsequently aligned to the implants. A loading force of 200 N was used to simulate centric occlusion and lateral excursion, and the principal stresses at the crestal cortical, trabecular and apical cortical bone were evaluated using finite element analysis. The authors found that, with centric loading, peak compressive stress was reduced at the crestal cortical bone with subcrestal placement, and that the forces were transferred to the trabecular bone, though peak tensile stress and strain were higher for the subcrestal implants with apical engagement in cortical bone. The authors concluded that stress in the cortical bone is reduced with subcrestal placement, but that displacement of the implants can be effectively limited by apical engagement of the implant in cortical bone. Compressive stress was more efficiently transferred towards the trabecular bone on eccentric loading, but for implants with the apex engaged in cortical bone, the peak compressive stress at the cortical bone was much higher than for the equivalent bone level implants. Subcrestal placement with apical engagement also showed less horizontal and vertical micromovement compared to either the subcrestal or bone level implants without apical engagement, effectively limiting implant displacement. Subcrestal placement of Neodent® Cone Morse implants therefore effectively reduced stress in the crestal cortical bone, efficiently transferring the forces to the trabecular bone.

Favourable peri-implant bone response

A number of studies have indicated that Morse taper implants have a lower risk of microgap and hence reduced biofilm accumulation, as well as a lower incidence of peri-implantitis [10], which may contribute to the consistently lower peri-implant marginal bone loss [4, 10]. For the Neodent® Cone Morse system specifically, the evidence also clearly indicates predictable crestal bone preservation with subcrestal implant placement.

Peri-implant bone resorption around Neodent® Cone Morse implants or implants with an external hex connection was investigated by de Castro and colleagues in dogs [23]. Nine implants of each type were placed in dogs; the Cone Morse implants were placed 2 mm below the crestal bone level, while the external hex implants were placed at the level of the crestal bone. The implants were retrieved after 8 weeks and evaluated; the mean distance from the top of the implant to the first bone-to-implant contact was measured, as well as the mean distance from the top of the implant to the original crestal bone level. Histological examination showed bone at the implant shoulder of the Cone Morse implants, with close connection to the abutment in some cases. Conversely, significant bone resorption was seen at the external hex implants (Figure 2).

The distance from the top of the implant to the original crestal bone level was not significantly different between the implant types, but significantly less bone remodelling was observed for the Cone Morse implants on both the buccal and lingual sides (mean 0.03 ± 0.08 mm buccal and 0 ± 0 mm lingual for the Cone Morse implants versus 1.69 ± 0.44 mm and 1.40 ± 0.63 mm, respectively, for the external hex implants). Crestal bone remodelling was therefore positively influenced by subcrestal placement of Cone Morse implants.

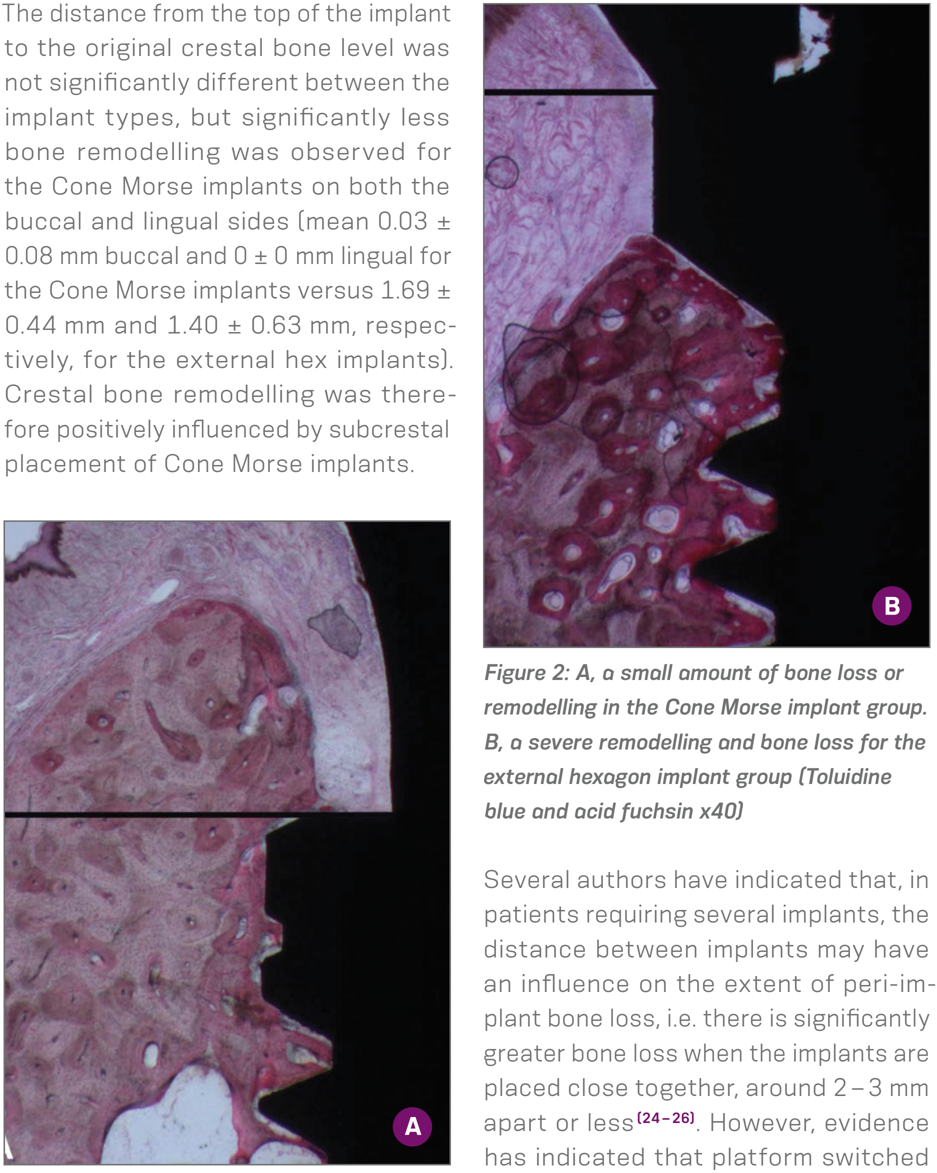

Figure 2: A, a small amount of bone loss or remodelling in the Cone Morse implant group. B, a severe remodelling and bone loss for the external hexagon implant group (Toluidine blue and acid fuchsin x40)

Several authors have indicated that, in patients requiring several implants, the distance between implants may have an influence on the extent of peri-implant bone loss, i.e. there is significantly greater bone loss when the implants are placed close together, around 2 – 3 mm apart or less[24 – 26]. However, evidence has indicated that platform switched implants with a Morse taper connection may mean that implants can be placed closer together with no significant loss of bone [27]. A study by Barros and colleagues showed that this was indeed the case with Neodent® Cone Morse implants placed subcrestally [28]. The authors placed eight implants in each of six dogs; the implants were placed either at the bone crest level of 1.5 mm below, with either 2 or 3 mm between the implants. Metallic crowns were immediately placed. The amount of bone resorption at the implants and in the inter-implant area was measured after 8 weeks. Subcrestal placement resulted in significantly less bone resorption than placement at the bone crest level for inter-implant distances of both 2 and 3 mm, and some of the subcrestal implants showed no resorption at all. Vertical bone resorption at the inter-implant area was also lower for the subcrestal implants. Good bone density and bone-to-implant contact was observed in all groups. Subcrestal placement therefore showed predictable bone preservation, even with implants only 2 mm apart, and the lower vertical resorption may have a positive influence for areas of aesthetic concern.

The effect on papilla formation as well as bone resorption was evaluated by Novaes and colleagues [29]. Again, eight implants were placed in each of six dogs, this time either 2 or 3 mm subcrestally or at the bone crest level, with inter-implant distances of 2 or 3 mm and immediate placement of metallic crowns. After 8 weeks, the distance from then implant shoulder to the first bone-to-implant contact, and the distance from the contact point of the crowns to the top of the bone crest and to the tip of the inter-implant papilla was measured. Both crestal bone preservation and papilla formation were superior in the subcrestal implants, with significant differences from the bone level group for bone preservation at both inter-implant distances, and for papilla formation at the 3 mm inter-implant distance. As with the study by Barros and colleagues, the authors suggested that the results may have particular benefit in aesthetic regions.

To answer the question of this suggested benefit in aesthetic areas, Martin and colleagues evaluated Neodent® Cone Morse implants in the aesthetic region of nine patients [30]. The patients received a total of twelve implants to replace teeth in the anterior maxilla; the implants were placed immediately after tooth extraction. Peri-implant bone mesial and distal to the implants was measured, as well as the height and width of the buccal wall. A slight gain at the distal aspect of the marginal bone crest (mean 0.07 ± 1.58 mm) and a slight loss at the mesial aspect (mean -0.14 ± 0.41 mm) was observed (Figure 3). However, there was significant increase in bone where the bone meets the implant surface at the mesial aspect (mean 0.92 ± 1.29 mm), while there was a smaller increase at the corresponding point on the distal aspect (mean 0.43 ± 1.63 mm) (Figure 3). There was a small, non-significant loss of buccal wall height (mean -0.20 ± 0.51 mm), much smaller than that observed in similar studies[31, 32]. The loss of buccal bone width from placement to 8 months was significant at the implant-abutment level and at 3 and 6 mm apical to the junction (mean values of -0.77 ± 0.75 mm, -0.59 ± 0.76 mm and -0.46 ± 0.81 mm, respectively), but again these values were lower than those observed in a similar study[32]. In addition, the authors did not see any signs of gingival recession during the study. The extremely favourable results were suggested to be a result of the implant geometry and type, as well as their position below the bone level and the surgical and prosthetic procedures used.

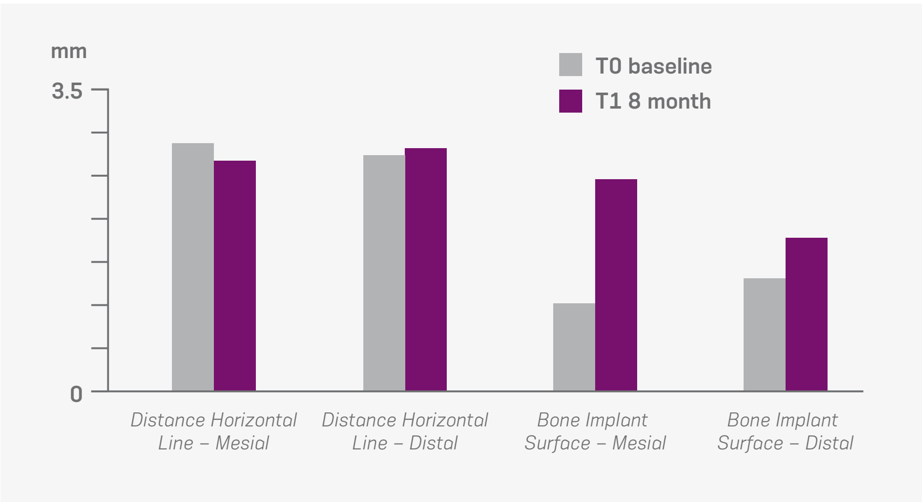

Figure 3: Column graph showing proximal level data at baseline and 8 months

Conclusion

The available evidence from studies with Neodent® Cone Morse implants shows that the connection has several advantages for both clinicians and patients. It is extremely effective in preventing bacterial migration either into or out of the central chamber of the implant, greatly reducing the risk of peri-implant biofilm build-up that can lead to inflammation and compromised tissue. The connection shows excellent biomechanical strength and mechanical resistance. For example, it results in very low stress forces on the abutment screw and in the crestal cortical bone, is highly resistant to bending forces, and shows good strain values under compressive loading, especially for the 5.0 mm diameter implant. The implants have also demonstrated superior crestal bone preservation, low vertical bone resorption with the implant-abutment junction situated below the crestal bone level. The system also shows good soft tissue stability and a natural, aesthetic emergence profile, indicated by papilla formation, supported by the lack of peri-implant bone resorption; this may be particularly useful in aesthetic areas.
The system can therefore be used in a variety of clinical situations, especially where predictable peri-implant bone and soft tissue maintenance is crucial.

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